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FIRST BOOK OF CHEMISTRY

BY —

MARY SHAW-BREWSTER

D. APPLETON & Co
NEW YORK

Educ T 228.87.230

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FIRST BOOK

OF

CHEMISTRY

A COURSE OF SIMPLE EXPERIMENTS
FOR BEGINNERS
AT HOME AND IN PRIMARY SCHOOLS

BY
MARY SHAW-BREWSTER

NEW YORK
D. APPLETON AND COMPANY
1887

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To the Memory
OF MY FRIEND
EDWARD L. YOUMANS,
AND TO HIS SISTER,
ELIZA A. YOUMANS,
I DEDICATE THIS BOOK,
IN GRATEFUL RECOGNITION OF THEIR INCENTIVE,
ENCOURAGEMENT, AND ADVICE.

PREFACE.

THIS book has been prepared for the guidance of children in the simplest preliminary chemical operations. It aims to stimulate in the beginner, by the natural method of observation and experiment, a desire to know about every-day phenomena—to lead him to question for himself, and then to answer his own inquiry, not by appealing to book or teacher, but by reference to the facts presented. The object being to develop thought that will lead to investigation, not to burden the memory, the pupil is told but little except *how to proceed.* Doubtless, in many cases mistakes will be made, or he will fail to draw any inference; but the habit of looking for a meaning, of tracing the relation between cause and effect, is of value, and the mind thus trained constantly seeks to verify its conclusions.

The experiments are extremely simple, and an effort has been made, not only to adapt the work to conditions found in the school, but to make it possible for a child to carry it on at home. To this end, the simplest apparatus is employed, and the range of material is limited to what the kitchen affords, and to a few well-known chemical compounds. Minute directions are given for the use of such reagents as involve the least element of danger. A child endowed with reasonable caution may safely be trusted to do all the work alone. Questions involving chemical theory are mainly avoided, the words *atom* and *molecule* are not mentioned, and nomenclature is merely introduced by a few symbols.

While the needs of such children as show a special aptitude for natural inquiry, and are without the advantages afforded by systematic guidance, have been in mind, and therefore an effort made to render the work helpful to those who *will* help themselves, it has been none the less obvious that the larger number of children are associated with companions in the school-room. And the question naturally arises, How can each one carry on this work of individual observation in the class? Certainly not by any method of mere lesson-learning and lesson-reciting; but *with the proper appliances*, and in the hands of a judicious teacher, excellent results may be expected here. There is not the slightest reason why, in a well-appointed school, there may not be time for work as well as time for study, and this is entirely consistent with due regard to order and quiet. Each member of a class may perform the experiments under the invaluable stimulus of one trained to careful habits of thinking and observation. Adroit questions will serve to lead the mind in the right direction; at the same time opportunity should be given the pupil for the exercise of individual inquiry. The use of a note-book, in which the results of each day's work are recorded, and revised by subsequent discoveries, is strongly urged. This record of the work should be subject to the daily inspection and comment of the teacher.

Indeed, this plan needs no other proof of its value than the fact that it has already been adopted, and is in successful operation for older pupils, in some of our best schools—and, if for older pupils, then why not for children? It is the child whose irrepressible activity shows itself in curiosity, and in a constant desire to handle things and to "try" them.

It is proper to state here that these experiments have been tested by actual practice. Most of them have been performed by children between eleven and fifteen years of age. These children were farm-lads, trained, not by school methods, but by daily contact with the ever-changing problems presented by outdoor life. The interest manifested in the work, the quick perceptions and ready inferences, were in striking contrast to the dullness which distinguishes much of the ordinary class-room work.

No claim to originality is made. The material has been gathered from all available sources, but Stockhardt's "Experimental Chemistry," Youmans's "New Chemistry," "Introductory Chemical Practice," by Caldwell and Breneman, "Easy Introduction to Chemistry," by Arthur Rigg, Roscoe's "Chemistry," Howard's "Practical Chemistry," and Clarke's "Elements of Chemistry," have been of special service.

DIRECTIONS FOR WORK.

Just as study implies some conditions for its successful prosecution, so does the work laid out in the successive exercises of this book. The first necessity is *a place for it.* This may be simply an old kitchen-table, or an ordinary room set apart for experimenting. All chemical work, even the simplest, can be done most conveniently in a room devoted to it exclusively. In this room, there should be water and a sink, either within the room or just outside. It should also be supplied with tables, and shelves and drawers, to hold the apparatus and chemicals not in use.

When a room can not be reserved for this special purpose, it may still be possible to have a large table, and cupboard or shelves devoted to it; the latter will hold all articles not in daily use, and the former will serve for work. Clean water can be brought in pails before school-hours, and waste water can be carried from the room when the exercise is over.

Wherever the work is carried on, attention should be paid to order and cleanliness. Avoid hurry; nothing is gained by it; on the contrary, only careful, deliberate, painstaking effort will bring any satisfaction. In childhood, good habits are easily formed. If everything has a place, and everything is in its place when wanted, plainly both time and space are economized thereby. Do not put vessels away dirty, but after each exercise clean the apparatus and restore it to its proper place. Some teachers recommend that all unused materials and vessels be placed at the left hand before beginning work, and moved to the right after they have been used, thus leaving a space in front for work. This may be a convenient arrangement, but it is not of the utmost importance that all pupils should follow exactly the same order. Attention to certain general principles is entirely consistent with the exercise of individual taste or peculiarity.

Look over beforehand each exercise, in order to provide whatever material is needed for the following day's work; otherwise it will frequently happen that something is wanted which can not easily be got. This can be attended to by either teacher or pupil.

Do not waste material, although much of it is inexpensive and easily obtained, and be sure to have each kind put aside carefully labeled. In the case of the strong acids, see that the bottles are restored to the shelves with their stoppers in. Use the simplest apparatus which will answer the purpose.

Each pupil will require a note-book, in which to keep a record of the daily work. Here let all discoveries be recorded, and also any doubt or question which may arise. The work of the following day may throw light upon the matter. This note-book, subject to the inspection of the teacher, enables him to understand the child's mental state, and gives him a clew to the points which may require some comment.

But "where there is a will there is a way"; and the intelligent teacher, inclined to encourage this simple experimental work, will need but few suggestions. The text-book in his hands is merely an assistant in his work of leading the pupil to habits of accurate observation and careful thinking.

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FIRST BOOK OF CHEMISTRY.

EXERCISE I.

Mixtures.

In studying chemistry according to the plan of this book, instead of lesson-learning you have something *to do*. By handling, observing, and working with substances, you will become familiar with some of their peculiar properties. And just as it is much more interesting to be acquainted with dogs and horses, and boys and girls, than to merely know them by their names, it is more interesting to study things by making their acquaintance—not by being told about them, or even reading about them.

The first thing to be done each day is to provide suitable materials for the exercise. Have everything ready when you begin to work; this will avoid delay and save time.

For Exercise I, get sand, iron filings, copper filings, flowers of sulphur, coarse Graham flour, very fine table-salt, and sugar. You will want only a small quantity of each of these. Iron filings can be obtained at a blacksmith's or machine shop; copper filings at the latter place, and both these will cost but a trifle. Flowers of sulphur can be bought at any country variety-store, or at a druggist's. Of this it will be well to buy half a pound, and, what you do not use in this exercise, label carefully, and put aside for future use. It is a soft, yellow powder, sometimes used for medicine. The fine salt, flour, and sugar are, of course, to be found in any kitchen or grocery.

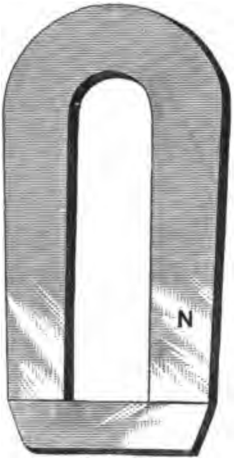

Fig. 1.

In addition to these materials, you will want a *very fine* hair sieve,* the finer the better, a horseshoe magnet,† and a sheet of letter-paper.

Now, with the things at hand, you are ready to go to work; and bear in mind that, in performing any single given experiment, you *must follow the general directions* for it, otherwise this, which simply means the doing something in order to discover a principle or truth, may fail, and you have thus lost time, wasted material, and gained nothing. On the other hand, you may perform the experiment successfully, but fail to see what it is intended to teach. In either case, it will be best to try it again with closer observation.

Experiment 1.—Mix well together some coarse

---

* A small sieve, frequently used in the kitchen, will cost but a few cents.

† Magnets are found in hardware stores or toy-shops; small ones can be bought for ten or fifteen cents, according to their size.

Graham flour and fine table-salt. Put this mixture on a *very* fine sieve, and, by sifting, see if you can separate any of the flour from the salt. What result?

EXPERIMENT 2.—Mix three parts of iron filings with one part of flowers of sulphur; sift as in the previous experiment. Can you separate the sulphur from the filings?

EXPERIMENT 3.—Mix equal quantities of sugar, salt, and sand together. Pour boiling water into this mixture; stir it to dissolve all you can of the solids, and then leave it to settle. Taste the water. Have you separated any of the ingredients? *

EXPERIMENT 4.—Again, mix iron filings with flowers of sulphur. Take half this mixture (reserve the remainder for the next exercise) and put it on a sheet of white paper; then *slowly* draw a magnet *just above* the paper, or under it.

EXPERIMENT 5.—Mix a few copper filings with sulphur; rub them together thoroughly, and closely examine the mixture to see if you can distinguish one ingredient from the other. Save this mixture for the next exercise.

If the preceding experiments have been carefully tried, and at the same time thought about, the pupil will have discovered that in all these mixtures the ingredients not only retain their distinctive properties, but they may be separated by simple means. It also appears that mixtures are made by using the materials in any quantity, it not being necessary to weigh or even to measure them. Gunpowder is a good example of this kind of compound; it is made by mixing sulphur, charcoal, and saltpeter together. You could easily separate the saltpeter from gunpowder by means of boiling water. Glycerine will mix with water in any proportions; and by means of a simple process, explained in Exercise IX, these ingredients can be separated.

---

* Substances used to make the whole.

When the exercise is over, clean whatever apparatus has been used, and put it in its proper place. Neatness and order are necessary to successful work of this kind. Since a certain definite time is generally allotted to each class in school, it may often happen that the day's exercise must be discontinued before the work is completed. This can be done by leaving things in such order that when the work is resumed each pupil may know exactly where the materials were left, and be able to put his hands on them without delay.

EXERCISE II.

Chemical Compounds.

Provide for this exercise cooking-soda, cream of tartar, a few leaves of purple cabbage, strong vinegar, and boiling water, in addition to some of the materials used in yesterday's work. The purple cabbage can be had at almost any grocery in the winter or spring, and in the summer it is found growing in many country gardens.

A *crucible* is a small, baked clay melting-pot (see Fig. 2), made to endure great heat. One of these will be useful for heating the mixture in Experiment 4; but in place of it, some kitchen utensil of unglazed earthenware may be found to answer the purpose. Or, the mixture may be heated in a thin glass vessel (see test-tubes, Exercise IV) over a flame.

EXPERIMENT 1.—Taste separately a little undissolved cream of tartar and common cooking-soda. Can you distinguish one from the other?

Dissolve *half a teaspoonful* of soda in half a teacupful of boiling water; add to this dissolved soda *a teaspoonful* of cream of tartar. Taste the liquid in the cup, and observe if it is like or unlike either the soda or cream of tartar when undissolved and unmixed.

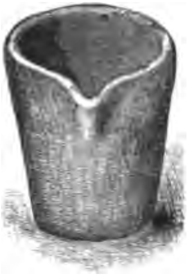

FIG. 2.

EXPERIMENT 2.—Burn a little sulphur in a dish in the open air. The sulphur will combine with something from the air and form a new compound which rises as smoke. Has this compound any odor? If so, is it from the air or the sulphur?

EXPERIMENT 3.—Make an *infusion* * of purple cabbage; this may be done by pouring hot or boiling water on to a leaf, leaving this to soak for half an hour, and then pouring off the purple water into another vessel. Add to the infusion a little strong vinegar. What change takes place?

EXPERIMENT 4.—Put the sulphur and iron mixture saved from Experiment 4, "Mixtures," into a crucible, if you have one; if not, into something which will bear a good deal of heat; put this into a clear coal fire. When the sulphur has entirely melted, take out the vessel, cool its contents, and try the effect of the magnet upon the melted mass. Can you now separate the iron from the sulphur as you did in Exercise I?

---

* *Infusion* is an extract from a vegetable substance in hot or cold water, made without boiling; a *decoction* is a similar extract made *by* boiling. Tea, as it is usually made, is a good example of the latter.

EXPERIMENT 5.—Repeat the above experiment, using the copper mixture instead of the iron.

If, as in Exercise I, the pupil has been very watchful and careful, he has discovered that the soda and cream of tartar, when mixed and dissolved, yield a compound which tastes not in the least like the ingredients; the sulphur gives a disagreeable smell when it burns; the water, stained by purple cabbage, instantly changes its color when vinegar is added; the magnet does not attract the iron filings from the sulphur when the mixture has been *strongly heated;* nor can the particles of copper be distinguished from the sulphur, even by means of a magnifying-glass. In other words, you have made *chemical compounds*, and these are unlike mixtures in having new properties, and in not being separable into their ingredients by the simple means used in the other case.

There is also another difference not so easily discovered. In mixtures, the materials are used in any or all proportions; but in chemical compounds only certain definite quantities are united. Thus, in the compound formed in Experiment 4, sixty-five grains of iron combined with just thirty-two grains of the sulphur; and if there was iron or sulphur in the mixture in proportions other than these, then the excess was left uncombined.

EXERCISE III.

Chemical Affinity.

PROVIDE for this exercise five cents' worth of lunar caustic, unslaked lime (a piece as large as an egg), a little sal ammoniac, a sheet of red litmus-paper (see Exercise XIII), and a clean pen. All these things you can buy at a drug-store for a few cents.

The lunar caustic will be in white sticks. It is *poison*, and you will need to use it with care, not only because it is corrosive, or eating to the flesh, but because when it is dissolved the liquid will blacken whatever it touches, and leave a stain which can not be washed off (see Exercise XIX).

Sal ammoniac comes in white, fibrous cakes or pieces. It is very tough, and, on this account, hard to pulverize.

In city schools, where buildings are lighted by gas, it can be used for heating substances. By means of what is known as the Bunsen burner (see Exercise XXVI), the ordinary gas-flame becomes hotter and less luminous. Wherever this can be used, it is the most convenient source of heat for chemical work. If this is not to be had, a small lamp in which alcohol is burned will be wanted. Provide also a mortar and pestle for grinding substances to powder.

But when these conveniences are not available, a little ingenuity will enable the pupil, in this case and many others, to devise ways and means for performing an experiment without much difficulty and with but little apparatus. For instance, a spirit-lamp can be made by perforating the cork of a wide-mouthed bottle, and inserting in this hole a small piece of glass tube to hold the wick (see Fig. 3). An old brass or iron thimble will serve for a cap to extinguish the flame, and to prevent the escape and waste of the alcohol.

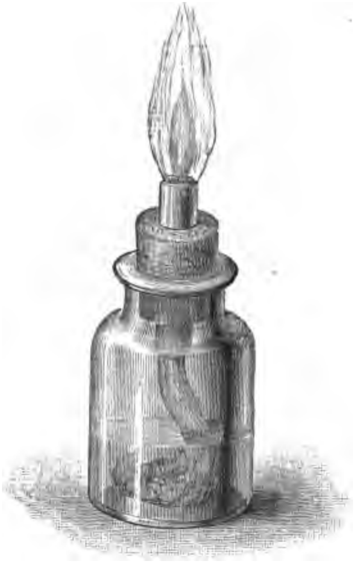

FIG. 3.

The mortar and pestle (Fig. 4) may be dispensed with by wrapping the substance to be pulverized in strong paper, laying it on a stone or brick, and pounding it with a hammer.

EXPERIMENT 1.—Mix sugar and salt, grind the mixture to bring the particles near together, and pour boiling water on it to dissolve the ingredients. Heat the mixture, either over gas, a spirit-lamp, or the stove, and finally, after the liquid has cooled, taste it to see if there seems to be any change of properties. Have you any reason to think that the mixture has become a chemical compound?

EXPERIMENT 2.—Put a lump of sal ammoniac, as large as the end of your finger, into a mortar, add to this about as much unslaked lime, and, after putting them together, smell them; also hold a strip of red litmus-paper over them. Is its color changed?

Now grind the lime and sal ammoniac together, and, when this is thoroughly done, smell again, and hold red litmus-paper over them. What change do you discover?

EXPERIMENT 3.—Make some indelible ink * by dissolving the white pieces of lunar caustic in a very little water, in a tiny bottle. Dip a clean steel pen or a quill pen into the solution, and write your name with it, on a piece of smooth muslin; expose this writing to strong sunlight. Also write on a second piece of muslin the same name, and immediately put it into a dark place. At the end of half an hour compare the two names. What is the difference?

FIG. 4.

EXPERIMENT 4. — Repeat Experiment 4, "Chemical Compounds." What agency seemed to change the mixture to a chemical compound?

EXPERIMENT 5.—Put a lump of unslaked lime as large as a butternut into a tin basin; pour cold water slowly over it (Fig. 5), and hold your hand over the lime; also feel the outside of the tin dish. What accompanies chemical union in this case?

In the experiments in this, as well as in the pre-

---

* If you have indelible ink, it will serve the same purpose as dissolved lunar caustic.

vious exercise, you have met some unexpected results. Sal ammoniac and lime, when thoroughly ground and mixed together, yielded a strong odor, like smelling-salts; when cold water was poured on unslaked lime, it seemed as if a fire had been kindled, so much heat was given out; and purple-cabbage water became green the moment vinegar was added! How can these changes be explained? If you ask the chemist to account for these curious results, he will probably tell you that a force called *chemical affinity* has been operating here; and if you ask him to explain still further what this is, he will reply that "it is an attractive force."

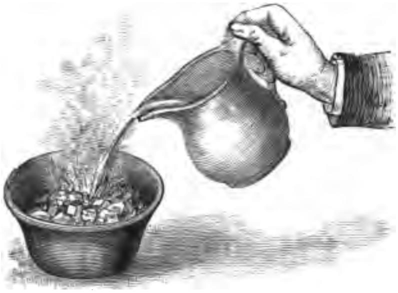

FIG. 5.

Perhaps you have learned in natural philosophy that cohesion, adhesion, and gravitation are attractive forces, and you ask, "Which of these is the new force like?" Let us consider. Cohesion is attraction between the same kinds of matter acting when the particles are close together; adhesion, attraction between unlike particles; and gravitation, the force which acts at all distances and between all kinds of matter. All these agree in one particular—that is, in not changing the material acted upon; but whenever this other force — chemical affinity — operates, substances *are* changed. Just *what* this new power is, no one knows, but its effects can be studied, and how and when it acts. One thing we have already discovered—this is, that when certain substances are brought into close contact, they disappear; and new ones, having qualities unlike either of their ingredients, appear.

Those substances which unite are said to have an affinity for each other. The strength of this attraction varies greatly in different cases. Sometimes it is so intense that combination takes place suddenly and with explosive violence, and again it is the slow work of days and weeks.

EXERCISE IV.

Solution.

WASHING-SODA, alum, saltpeter, and chalk are substances in common use; you will want small quantities of each. Also buy at a druggist's a quart of alcohol; this will be often wanted, especially if a spirit-lamp is much used. Keep the bottle containing it tightly corked, to prevent its evaporating.

A test-tube, some beakers or kitchen-cups, and a thermometer, will complete the outfit for this day's work.

Test-tubes and beakers are thin-bottomed glass vessels, adapted to withstand heat. The former (Fig. 6) can always be used in experimenting with small quantities of liquids or solids. Two sizes can be obtained, and when bought in quantity they cost only two or three cents apiece. By all means have a stock of these on hand, for they will often take the place of much more expensive things. Test-tubes can be cleaned by means of a bit of sponge fastened either to a stick or wire.

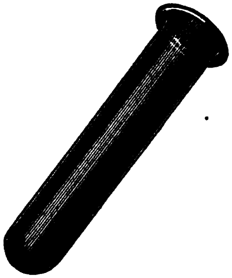
FIG 6.

Beakers (Fig. 7) are sold in *nests* of different sizes; they are the most convenient vessels for heating other than small quantities of liquids, but, *with care*, many things can be done by means of thin kitchen-cups and common tumblers; the latter can not safely be heated. When heat is to be applied to vessels, stand them on a tripod or in the ring of a retort-stand (see Figs. 8 and 9). Protect them from the naked flame by a piece of wire gauze or a sand-bath (see page 42).

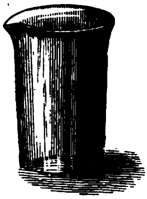
FIG. 7.

Apply heat slowly to all vessels used for heating liquids, and avoid putting them, when hot, in contact with cold surfaces.

A thermometer is a heat-measurer. It is constructed on the principle that heat expands substances, and cold causes them to shrink or contract. Perhaps you have noticed that water often runs over from the tea-kettle when it is heated. The expansion and contraction of this liquid might be used to mark different degrees of heat, but mercury is more commonly used because it boils at a higher temperature and freezes at a lower one. It also expands more regularly.

To make a thermometer, the mercury is inclosed in a small glass tube, at one end of which there is a little bulb or sac. The air is driven out of this tube and the upper end is closely sealed. When heat is applied, the mercury will be seen to rise slowly in it; and when it cools, the mercury shrinks back into the bulb, or contracts. In order to tell *how much* or *how little* expansion there is, a little scale is attached, marked in degrees. To get a starting-point on this scale, the closed tube of mercury is placed in melting ice and left there until the mercury comes to a standstill. This point is the freezing-point of water. Sometimes it is called the *zero*-point—that is, the nothing-point. A mark is made on the glass corresponding to it. The tube is next plunged into a vessel of boiling water, and the mercury rises to a point where it stops expanding, at the boiling-point of water. A second mark is made on the tube, and between these two marks the space is divided into degrees.

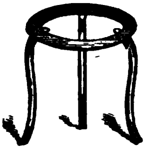

FIG. 8.

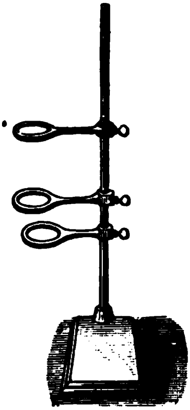

FIG. 9.

On the thermometer scale most used in this country, called the Fahrenheit scale, the space between the "boiling" and "freezing" is divided into 180°.

The centigrade thermometer is exactly like the Fahrenheit, except in its marking. On the former the space is divided into 100°. If you immerse a thermometer of each kind in boiling water, the mercury in the centigrade will rise to 100°, in the Fahrenheit to 212°; plunge them into melting ice, and the lowest mark—*zero* centigrade—will correspond to 32° Fahrenheit. Fig. 10 shows the different scales.

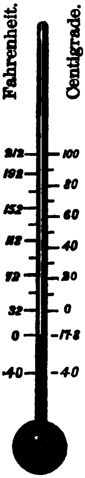

FIG. 10.

EXPERIMENT 1.—1. Fill four cups, or beakers, of the same size, each just half full of cold water; add to one cup two tablespoonfuls of common salt; to the second, the same quantity of sugar; to the third and fourth, the same quantities of powdered washing-soda and chalk. Stir well to dissolve the substances, and carefully observe the liquids. Which dissolved most quickly, salt or chalk? Is the water in the different cups clear or cloudy?

2. If there should remain undissolved matter in any of the cups, heat these to the boiling-point (212° Fahr.). This can be done over a spirit-lamp or on the stove, but in either case apply the heat gradually, stirring the contents of the cups meantime, to avoid breaking them.* When the water boils, look to see if the solid has all disappeared.

---

* Any sediment at the bottom of a liquid in a vessel is liable to produce a peculiar bumping noise when heat is applied. To avoid danger of breakage from this, shake or stir constantly.

3. If all the solid has disappeared in any of the cups after the heating, add another tablespoonful, stir thoroughly, and heat to the same point again. Continue this treatment until a little undissolved matter remains in each cup. Finally, let the liquids cool, and note any further change.

The liquid used to dissolve a solid is called the *solvent*, and the process is *solution.*

If you refer to Experiment 2, in the last exercise, you will remember that the substance called sal ammoniac, when mixed with lime, gave out a peculiar odor, and that litmus-paper, when held over the mixture, changed from red to blue; and, if we go a little further back to the subject of "chemical compounds," we learn that this change of color is one of the indications of chemical union; but observe—*the test-paper showed no change of color until the particles had been brought together by grinding and pressure.* That chemical union may take place, it is often necessary not only to pulverize things but to dissolve them, in order that their particles may have greater freedom of movement.* The particles of a dissolved substance are much more finely divided than in the case of mixtures. You have discovered by the experiment given above, that the minute grains can not be seen in the liquid, and that none of them settle at the bottom (when once dissolved) unless some water has evaporated.

When a liquid has dissolved all it can of a solid, it is said to be *satisfied* or *saturated.*

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* In all cases solution may be hastened by breaking up the lumps, and by bringing fresh portions of liquid into contact with solid matter by shaking or stirring.

Experiment 2.—Make a saturated solution of lime-water, by pouring a quart of cold water on a piece of unslaked lime as large as a butternut, in any vessel, allowing it to stand six hours undisturbed, and then pouring off the *clear* liquid into a large bowl.

Expose this clear lime-water to the atmosphere for twenty-four hours, and then note any change in its appearance.

Also fill a bottle with clear lime-water, cork * it tightly, and reserve it for Exercise VII.

Experiment 3. — Make a saturated solution of sugar in hot water; allow it to cool, and note the difference between the cooled and the hot liquid.

Experiment 4.—Make the same observations on alum solution. Is water satisfied more quickly by sugar or alum?

The previous experiments show that some solvents are much more easily or quickly satisfied than others. Generally, it takes more to satisfy hot liquids than cold; but careful experiment proves that *the limit is always the same for the same substance when heated to the same degree.* In one or two cases cold water will dissolve more of a solid than hot water will. Can the pupil think of any case in which this is true?

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* It is well to roll corks between two hard surfaces before fitting them to bottles or test-tubes. This softens them, and by means of a slight twist and a little pressure they may be made to fit very tightly.

EXERCISE V.

Tinctures and Change of Temperature in Solution.

Buy at a druggist's five cents' worth of camphor-gum, five cents' worth of Glauber's salts, and a small bottle of hydrochloric acid.* Add to this collection some green leaves and the petals from bright scarlet and yellow flowers. Turn to page 57 for directions in using the strong acids.

Experiment 1.—Put a piece of camphor-gum as large as a chestnut into a wineglass of water. Will it all dissolve?

Experiment 2.—Put a piece of camphor-gum of the same size as that used in Experiment 1 into a wineglass of alcohol, and, if it dissolve, save the solution for Exercise VII.

Experiment 3.—Soak half a dozen fresh, green leaves in water, and put as many more into alcohol, and let them remain the same time. What difference do you discover?

Experiment 4.—Repeat Experiment 3, using, instead of green leaves, the petals of any yellow flower; also, try the same with bright geranium-petals.

Water will dissolve so many things that it is often spoken of as the *universal solvent.* Its use in cooking and cleaning is due largely to this power which it has of dissolving or extracting the qualities of substances. The soup we eat, and the tea we drink, as well as the tinctures prescribed by the doctors, are all solutions of some kind.

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* Hydrochloric acid is frequently called muriatic acid.

Tinctures are non-volatile * substances dissolved in alcohol. Originally, the word tincture meant something to which a tint or color had been given, but now it often means an extract to which any other quality than color has been imparted.

Volatile substances dissolved in alcohol are called spirits of those substances—as *spirits of camphor.*

There are other solvents besides water and alcohol. Ether and the strong acids dissolve a class of substances not acted upon by the common solvents, and air dissolves water as water dissolves solids. There is water in the air in the clearest day, although we can not see it, for the same reason that we can not see salt and sugar when they are dissolved in water.

EXPERIMENT 5.—Dip a common thermometer-bulb into a cup of cold water and *carefully* note the temperature of the water; dissolve as much salt as you can in the same cup of water, and afterward test the solution by the same thermometer. What do you discover?

EXPERIMENT 6.—Repeat Experiment 5, using, instead of salt, saltpeter. How does the saltpeter solution differ from the salt solution?

EXPERIMENT 7.—Fill a common tumbler almost full of Glauber's salts; pour over this powder hydrochloric acid enough to thoroughly wet it. Now plunge into this moistened powder in the tumbler a small test-tube, into which you have poured a little water, and, after leaving it for a minute or two, note what has happened.

This process of solution, though very simple, is interesting and important; it prepares the way for chemical affinity by bringing the particles near together. This is easily illustrated by a kitchen experiment which you will remember under "Chemical Compounds." The cooking-soda and the cream of tartar, in Experiment 1, united when the soda had been previously dissolved in water; but, if the two substances had been mixed dry, they would have remained a mixture. The water, however, dissolved the soda, and, immediately upon the addition of the cream of tartar, violent foaming or effervescence took place, and chemical union was the result. Ginger-beer and Seidlitz powders are other familiar illustrations of mixtures which show no affinity for each other until solution takes place.

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* *Volatile*—having a tendency to escape into the air—to evaporate.

EXERCISE VI.

Crystallization.

Add to the stock of materials already provided, an ounce of blue vitriol, an ounce of gum arabic, and a piece of glue. Washing-soda, alum, saltpeter, sugar, and salt will also be used.

Blue vitriol is a poisonous compound of sulphur, copper, and oxygen, which you can safely handle, but must not taste. It is used in galvanic batteries and in calico-printing.

Increase your stock of apparatus by a Florence flask, a pocket magnifying-glass, a clay pipe, and a measuring-glass; and have at hand a piece of window-glass and an iron spoon. The flask is a narrow-necked bottle (see cut) of thin glass, and so named because, years ago, olive-oil was brought from Florence in similar bottles. Like test-tubes, these bottles will bear heat well, and be useful in many ways. They cost a little more, the usual price being twelve or fifteen cents apiece. The pocket magnifying-glass is a small one, which folds into a horn case, and which you may have already used in examining botanical specimens. The measuring-glass is a convenient vessel for measuring and pouring liquids. It has a scale attached, and a pitcher-shaped mouth, from which liquids pass without spilling (see Fig. 12). It is not, however, a necessity.

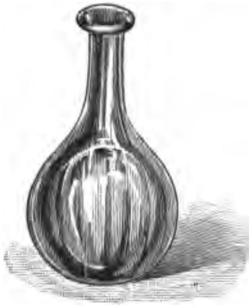
FIG. 11.

EXPERIMENT 1.—Make a saturated solution of common washing-soda by dissolving as much as you can in a test-tube half full of hot water. Leave the solution undisturbed for a day, and then observe the sides of the test-tube.

EXPERIMENT 2. — Make similar observations to the above on a saturated alum solution.

The particles of soda and of alum seen on the sides of the test-tube in Experiments 1 and 2 are called *crystals*. The process by which these were formed is *crystallization*. The soda-crystals all looked alike in shape, and the alum-crystals looked alike; but the two kinds were quite

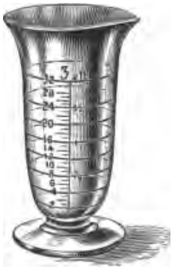
FIG. 12.

different. This uniformity of crystalline shape in the same substance which you discover, sometimes gives a useful clew leading to the detection of substances.

Experiment 3.—Dissolve as much common salt as possible in half a teacupful of boiling water; let the solution cool; then observe if any crystals have deposited. What inference may be drawn from this?

Divide the solution; set one half in a warm place, and boil away the water from the other half. At the end of two days, look at that left in the warm place, and compare it with the part which the water was boiled away from. What difference do you discover in the shape of the crystals?

Experiment 4.—Dissolve an ounce of white sugar in half an ounce of hot water. Pour the solution into a clean bowl, and leave it in a warm place to slowly evaporate. Observe, when the crystals form, if they differ from salt-crystals deposited in the same way.

Experiment 5.—Pulverize half an ounce of alum, also half an ounce of blue vitriol, either by grinding them in a mortar, or by the method explained in Exercise III. Mix the powdered alum and vitriol well together; dissolve this powder in eight teaspoonfuls (an ounce) of hot water, and leave the solution undisturbed twenty-four hours. Observe the crystals, and note any peculiarity.

Experiment 6.—Make a solution of gum arabic by dissolving half an ounce of the gum in an ounce of cold water. At the end of a week, examine the solution for crystals.

Experiment 7.—Examine under a small pocket magnifying-glass pieces of glue, gum arabic, and glass;

also the deposits from the solution of alum and blue vitriol.

EXPERIMENT 8.—Put a teaspoonful of powdered saltpeter into a teaspoonful of cold water in a test-tube. Gradually bring the test-tube to the flame of a spirit-lamp, slanting it a little to avoid too sudden exposure to the heat. When the water is heated to the boiling-point, the powder will probably have dissolved, but, if not, shake it, and boil for an instant. Pour the solution out, and set it aside to cool. When crystals have deposited, put them on blotting-paper to dry, and then look at them through the magnifying-glass. What shape have they?

NOTE.—These experiments may be extended by using bichromate of potash, prussiate of potash, and copperas. The first will give deep-red crystals; the second, yellow; and the third, green ones.

If you have carefully performed the experiments in this and in the preceding exercise, and thought about them as you watched the rearrangement of particles, you have no doubt seen that crystallization is the opposite of solution. This process is essentially the same, whether it goes on during a snow-storm, giving us forms of surpassing beauty (see cut), or by the slow cooling of substances that have been in solution.

Crystals abound everywhere in nature. We see them as snow, frost-work, and in minerals. They vary greatly in size; some being so small that they can not be seen by the eye unaided, while others are so large that we could not possibly lift them. When this rearrangement of particles goes on slowly, the crystals are large and more nearly perfect; but when the change takes place quickly, they are small and imperfect. You must not conclude, however, that everything will crystallize, or show the least approach to regular structure. Such as do not are termed *amorphic*—meaning without form. A few substances crystallize in two, or even more different forms. These are *dimorphic* (two forms).

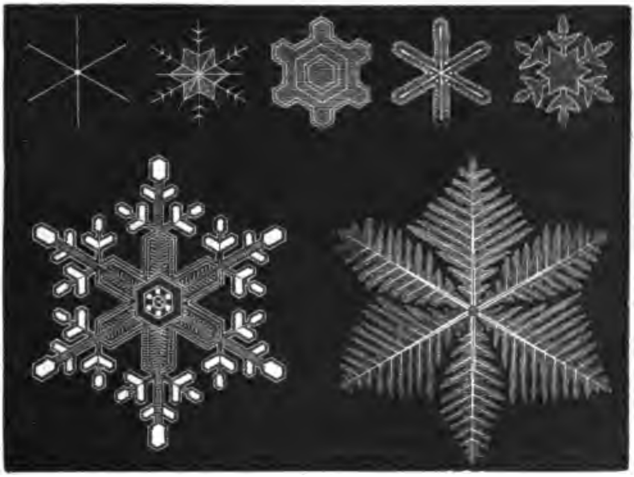

FIG. 13.

EXPERIMENT 9.—Put a few alum-crystals into an iron spoon, and hold this over the flame of a lamp, or over the fire. What happens?

EXPERIMENT 10.—Try the same experiment with a little saltpeter. What is the difference between this and the alum?

EXPERIMENT 11.—Fill the bowl of a common clay pipe with blue-vitriol crystals; heat as before, and observe what change takes place.

EXPERIMENT 12.—Put a few transparent crystals of

Glauber's salts on blotting-paper, and leave them exposed to the air for a few days; then note their appearance.

The crystals of some compounds contain water, even when they look perfectly dry. This *water of crystallization*, as the chemist calls it, is a part of the crystal, as you have seen by heating alum, which expelled it, leaving only a powder behind. Sometimes this escapes at ordinary temperatures; and when substances yield it naturally, gradually changing from crystals to a mealy powder, they are said to *effloresce*, or *flower*, as the word really means.

NOTE.—Some substances take water from the atmosphere. These are said to *deliquesce*—a word which means *to melt*.

EXERCISE VII.

Precipitation.

ONLY some small lumps of potash and copperas, and a glass tube or pipe-stem additional, are needed to-day. Materials which you have become familiar with in one exercise will not be enumerated in following ones. Spirits of camphor, a common household remedy, you obtained in Exercise V (Experiment 2). You remember that camphor-gum scarcely dissolved at all in water, but that alcohol quickly acted upon it. The old name for alcohol was "*spirits of wine*," and substances dissolved in it are either tinctures or spirits, as explained before.

Potash is an interesting compound to the chemist, and a useful one in the household, where it is used in soap-making. It can be bought at any country store or grocery. You could get it by boiling wood-ashes in water, and afterward evaporating the water from the solution. Until within a few years it was chiefly obtained from this source; now, the chemist understands how to get it elsewhere. It is said that a thousand tons are yearly obtained from the dirty water in which wool has been washed. The sheep, in feeding, take compounds containing potash from the soil; these exude in perspiration and adhere to the wool. Potash is eating or corrosive to the flesh, and care must be exercised in using it. Avoid touching it with your fingers; and if you have more than you want to use immediately, keep it in a tight bottle away from the moisture of the air. (For fuller directions, turn to the exercise on "Acids, Bases, and Neutral Substances.")

Copperas, or green vitriol, is another compound used frequently in the household. It comes in green crystals, which are poisonous; but this does not prevent its being very useful in destroying bad odors and cleansing sinks, drains, and foul places. Substances which do this are called *disinfectants*.

EXPERIMENT 1.—Pour a little clear water into half a wineglassful of spirits of camphor. What effect?

EXPERIMENT 2.—Blow for ten or fifteen minutes through a pipe-stem or a glass tube into a tumbler half full of perfectly clear lime-water. (This lime-water you prepared in Experiment 2, "Solution.") Observe if any change takes place in the lime-water, and save the contents of the tumbler for the next exercise.

EXPERIMENT 3.—Dissolve a crystal of blue vitriol in clear water; add to the solution a little piece of potash.

EXPERIMENT 4.—Dissolve a small lump of copperas in a test-tube half full of warm water. Into this drop two or three drops of nitrate-of-silver solution,* Experiment 3, "Chemical Affinity." Observe the fine powder which appears in the test-tube. What does it look like?

EXPERIMENT 5.—Boil and afterward cool a wine-glass of water; drop into it *two* or *three* drops of the nitrate-of-silver solution. Is the water discolored by this?

Dissolve a lump of common salt as *large as a pea* in a teaspoonful of water, and observe if the salt discolors the water. Finally, add the salt water to the water containing the nitrate of silver. What change?

The particles of solid matter which have disappeared in a solvent, and seem to be lost in it, may frequently be shown to be merely hidden among the particles of the solvent. Evaporating (boiling off the water, or exposing it to the slow action of the atmosphere) or cooling the liquid may show them still there. Their cohesion has been overcome for a time by a stronger force.

In the experiments above, the solid is separated from solution instantaneously by the addition of a third substance. When the separation is accomplished in this way, the solid obtained is the *precipitate*, and the process is *precipitation*.

Thus, when the water was added to the dissolved camphor, suddenly the particles reappeared; the clear lime-water became turbid or milky, because something was added from the breath (see carbonic acid). The other experiments illustrate the same process.

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* Lunar-caustic solution.

EXERCISE VIII.

Filtration.

STRONG, white blotting-paper, or even common newspaper, may serve for filtering; these can be used in an emergency, but *filter-paper* prepared for this purpose, which may be bought at any drug-store, is much better. Writing-paper will not do at all, because its pores are filled with starch or glue.

A funnel will be wanted to support the cut filter; this funnel, in turn, must be supported in the mouth of a fruit-jar, or in some kind of a ring. An iron ring-stand, sometimes called a retort-stand (see page 23), is useful for this purpose. If the latter is used, you will also need a tumbler or other glass vessel, into which the end of the funnel-tube should enter.

To prepare a paper filter, first cut a square of paper; next, fold this square through the middle; and again, at right angles to the first fold, or into quarters. Trim the edges to convert the square into a circle, and finally, open the folded paper so as to make a hollow cone, having three thicknesses on one side and one on the other (see Fig. 14). Place this paper cone in the funnel, moisten it with water, and press it gently with the fingers to make it more readily fit the sloping sides. The moistening can be done best by means of the *wash-bottle* (Fig. 15). This is a wide-mouthed bottle, with a sound cork, into which two tubes are fitted,

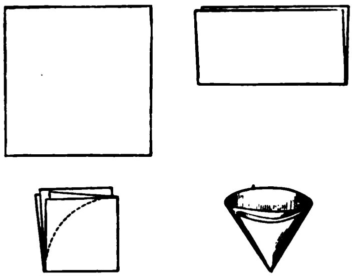

FIG. 14.

bent as seen in the figure. The obtuse-angled tube passes just through the cork; the other, which terminates in a jet or very small opening, passes to the bottom of the flask. The bottle is partly filled with water, and the mouth applied to the obtuse-angled tube. Air is forced in from the lungs, and the increased pressure from this drives the water up the second tube and out at its opening.

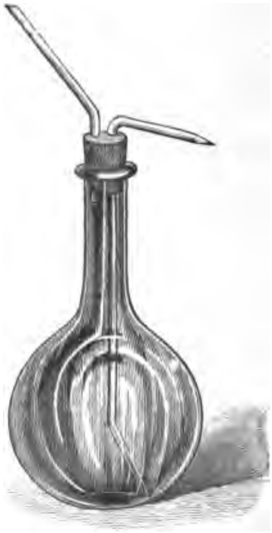

FIG. 15.

Like some other things which you have been told how to use, the wash-bottle is a convenience; but it *can be* dispensed with by the ingenious pupil, who may have at hand only such appliances as cups, bottles, tubes, and a lamp. The additional materials required for filtration are common dark vinegar, bluing used in the laundry, and muddy water.

EXPERIMENT 1. — Pour muddy water into a paper filter arranged as described above. Do not quite fill the filter with the liquid. The water will slowly drip through into the glass (Fig. 16). Notice if it looks as it did when you poured it into the paper.

EXPERIMENT 2.—Pass water, colored by common washing-bluing, through a filter, and compare the result in this case with that in Experiment 1.

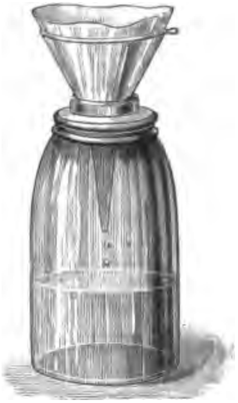

FIG. 16.

EXPERIMENT 3. — Filter* common, dark, cold vinegar. Observe the liquid which passes through. Filter an equal quantity of hot vinegar. Which goes through the filter most quickly —the hot or the cold?

EXPERIMENT 4.—Mix some fine, white sand with sugar, and pour boiling water on the mixture. Pour this—sand, sugar, and water—into a filter; and when the liquid passes through, taste to see what went with it—sand, sugar, or both together.

EXPERIMENT 5.—Filter the lime-water saved from Experiment 2, "Precipitation."

It often happens that solids are *mixed* with liquids, as in the case of running water in brooks and rivers. The water has washed sand and dirt from the banks of the stream and loosened it from its bed. Dirt of this kind would, much of it, settle as sediment if the water were undisturbed, but it may also be separated by this process of *filtration*. The clear liquid, after it has passed through the filter, is called the *filtrate.*

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* The porous material through which the liquid passes, and the process, are both often described by the same term: thus we say, *filter* the liquid; and, the *filter* is of paper.

The pupil will sometimes want to save the solid separated from the filtrate. In order to transfer this from the paper to any vessel, take the filter carefully from the funnel, and, after spreading it on a clean plate, scrape off the solid matter by means of a knife or spatula.*

In the experiments in this exercise only paper filters have been used; but sand, charcoal, or even a sponge may serve the same purpose. These porous materials all act like a sieve, letting the water and everything dissolved in it pass through, but retaining solid particles.

Decantation, which consists in pouring off a liquid carefully from its sediment, is often resorted to, instead of the more troublesome process of filtration.

EXERCISE IX.

Distillation and Sublimation.

Buy a few iodine-scales at any place where chemicals are sold—five cents' worth will be enough; they look like black-lead, only darker in color. This substance takes its name from its beautiful violet-colored vapors. It is used in the process of photography, in dyeing, and in medicine. It is poisonous when taken internally, but it is safe to handle it. A very little will serve for the experiment in this exercise, but you will want the remainder for Exercise XXV. Keep it in a glass bottle, tightly corked and plainly labeled.

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* A *spatula* is a thin, broad-bladed horn knife, used by the chemist to mix powders, etc.

The additional materials wanted are port-wine and glycerin, a small quantity of each.

The apparatus for distillation usually consists of a thin glass vessel with a bent neck, called a *retort* * (see Fig. 17). This is connected with another glass vessel —a receiver or condenser.

Instead of the retort, a Florence flask with a bent tube inserted in its cork, and this connected with another Florence flask to serve as a receiver, will answer. A common clay pipe may be used in place of the bent tube. Moistened paper wrapped around the stem or tube will make the connections tight (see Fig. 18).

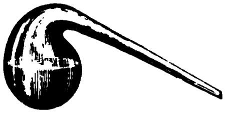

FIG. 17.

The liquid to be distilled is poured into the retort; heat applied underneath by a spirit-lamp causes the vapor to pass from one vessel to the other, where it is condensed. Wet cloths or moistened blotting-paper, wrapped around the receiver, will hasten

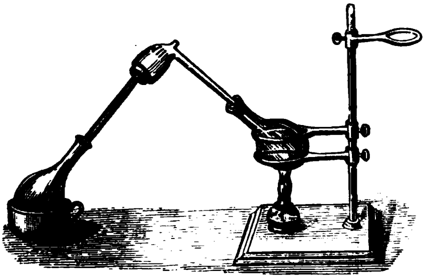

FIG. 18.

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* A small retort will cost twenty or twenty-five cents.

the condensation of the vapor. If the retort rests in a small sheet-iron dish filled with clean sand—called a *sand-bath*—the heat will be gradually conducted to the glass and all danger of an explosion avoided.

EXPERIMENT 1.—Fill a retort or Florence flask about half full of salt water; connect the neck of the retort with a receiver; apply heat by means of a spirit-lamp, and condense the steam in the receiver by wrapping it in wet cloths. Taste the condensed vapor. Is it like the salt water in the retort?

Boil off the remainder of the water in the retort, and notice if anything remains on its sides and bottom.

EXPERIMENT 2.—Distill, as in previous experiment, common bluing-water. What result?

EXPERIMENT 3.—Distill some dark-colored vinegar or port wine. In this case be careful not to apply heat too long, or until everything becomes vapor.

EXPERIMENT 4.—Mix glycerin and water; shake the mixture thoroughly, or until there seems to be perfect combination, and afterward distill the mixture. Can you separate the ingredients?

This process is named *distillation*, from a word meaning *to drop*. The pure liquid condensed in the second vessel is called distilled liquid.

A familiar illustration of this process is that of rain. Moisture from the earth's surface ascends in the form of vapor. When the air which carries the moisture reaches a colder region, it contracts or condenses; but condensed air can not hold so much moisture in its interstices * as expanded air can, and gives up the surplus. This in turn condenses or crystallizes, and falls to the earth as rain or snow. It makes no difference whether the process is watched by the chemist as it goes on in a retort, or on the gigantic scale by which all the waters on the earth's surface are distilled. In either case, the process is a purifying one.

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* Spaces between the parts.

By distillation a liquid may be separated from a solid dissolved in it, or one liquid may be separated from another, *if they do not become vapors at the same temperature.*

Experiment 5.—Put a little camphor-gum into a small Florence flask or thin glass bottle (the glass should be perfectly dry); cork it tightly, and expose it to direct sunlight for six hours; then observe the sides of the glass (see Fig. 19).

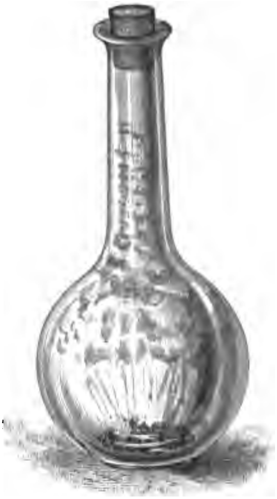
Fig. 19.

Experiment 6.—Put a few iodine-scales into a perfectly clean flask or bottle; cork, and heat *very* gently over a spirit-lamp.

Experiment 7.—Put some small lumps of sal ammoniac in a test-tube; heat this over a spirit-lamp, and when it becomes vapor, cool the test-tube and notice the appearance on the glass.

Solid substances which can be vaporized at moderate heat are purified by *sublimation.* The process is not very unlike distillation. The materials, at first, are heated, and afterward the vapor is recondensed by cold. The product, always solid, is called the *subli-*

mate. *Flowers of sulphur* are obtained from crude sulphur by this process.

EXERCISE X.

Glass-Working.

EVERYTHING necessary for the most simple or most elaborate chemical experiment can be bought ready made and fitted, and in large schools ample provision for chemical work is made; but apparatus is liable to be costly, and a little practice and contrivance will enable the pupil to make it at trifling expense, and with the further advantage of acquiring skill in adapting means to ends. As explained before, a common clay pipe will sometimes take the place of a bent tube; but often the latter is wanted; and with a little skill, straight glass tubes can be converted into bent ones. Buy a dozen *soft* glass tubes of different sizes and of medium thickness. They will cost only twenty-five cents. Ask for such as have no lead in them. This element in glass renders it too fusible, or liable to suddenly melt down.

To bend a glass tube.—Hold the tube in both hands while turning it constantly in the flame of a spirit-lamp. Allow the flame to strike about an inch of the tube where it is to be bent. When the glass softens a little, or yields to pressure, take it from the flame and bend it slowly, keeping the convex part next to you (see Fig. 20).

Cool the tube gradually by resting it on something which will conduct the heat from it slowly.

Note.—In working glass avoid all draughts; even the moving of persons in the room will render the flame unsteady.

To close a tube at one end.—Heat the tube as for bending; take it from the flame, and draw steadily apart the two portions of the tube on each side of the heated space; finally, close the end by reheating it in the flame.

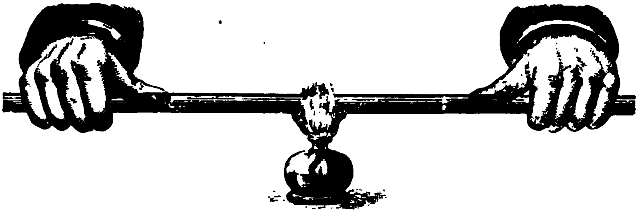

Fig. 20.

Bulbs or sacs may be blown in glass tubes at the end or in the middle; but this is a very delicate operation, and it requires much practice to insure success. It is done by closing one end of the tube, applying heat at the point where the sac is to be made, and, when this spot becomes red hot, removing it from the flame, and blowing gently and steadily in at the open end to expand the soft glass. This must be done cautiously; and as soon as the glass is seen to enlarge the force should be lessened.

Glass-cutting is done by a glazier with a diamond; but as the pupil is not likely to have one, he will want, instead, a sharp three-cornered file. Success in this work depends much upon the thickness of the glass, as you will discover in practice.

To cut a glass tube.—Make a notch at the point where you want to cut it by slightly moving the tube along the edge of a file; afterward, grasp the tube with both hands and break it, holding the notch from you.

If the tube is a large one, mark it all the way around by the file, in addition to the deep notch on one side.

EXERCISE XI.

Decomposition.

Red oxide of mercury is, as its name implies, a red powder. It is a poison, but, like iodine, it can be safely used for experimenting. An ounce of it will cost ten or fifteen cents, but half that quantity will be enough for the following work. Red litmus-paper and chalk you have already used, and probably have them on hand.

A *pneumatic trough* is a vessel used for collecting and transferring gases over water. These vessels are usually made of sheet-zinc, or earthenware, and a school will be likely to have one. A substitute can be made out of a common wooden pail, or small tub, by placing a shelf inside, about half-way between the top and bottom. Near the middle of this shelf a hole should be cut, about half an inch in diameter.

Under the hole in the shelf a tube of some kind will carry gas to a bottle or glass jar placed on the shelf, just over the hole. The accompanying cut will give a clear idea of the apparatus, and practice will show you how it is used.

Pour water into the pneumatic trough until its shelf is about an inch under water. Fill a glass jar with water, place the palm of your hand over its mouth, and quickly invert it under water in the

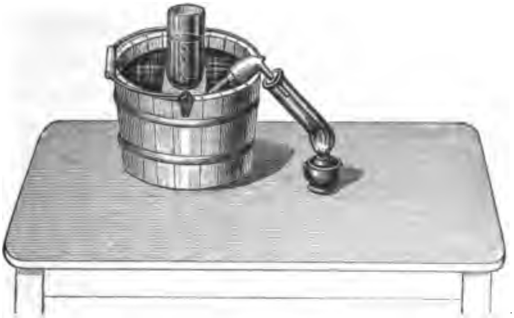

FIG. 21.

trough; now very carefully slip it on the shelf, so that its mouth is over the hole, taking care that water does not escape and air-bubbles occupy its place. Finally, adjust a bent glass tube so that one end will extend *just under the hole* in the shelf, and, at the other end, blow air from your lungs into it. Observe what takes place in the jar when you blow into the tube. How do you account for the change? In place of the bent tube a clay pipe, with the stem of a second one fastened into the bowl, may be substituted. The connection may be made perfectly tight by means of moistened paper wrapped around the stem.

EXPERIMENT 1.—Put a little red oxide of mercury into a glass, and try to dissolve it in warm or cold water.

EXPERIMENT 2.—Put as much red oxide of mercury as you can take up on the end of a penknife-blade into a test-tube, and heat it *slowly* over a spirit-lamp.

A handle by which to hold the test-tube over the lamp can be made by passing a wire around the tube and twisting its ends together. Observe the changes which take place in the powder, while the heating which must be continued a long time, goes on. Finally, touch the deposit on the sides of the glass with a glass rod or knitting-needle. What do you seem to have in the tube? Is it like anything you have seen before?

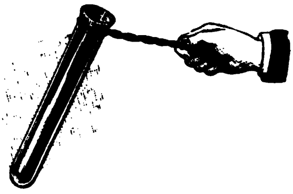
FIG. 22.

EXPERIMENT 3.—Measure out about half of the red oxide of mercury which you bought, and put it into a test-tube. Connect with the mouth of this, by means of a tightly fitting cork, a bent glass tube, which will terminate under the hole in the shelf of the pneumatic trough. Fill a jar with water and invert it over the hole, as explained before. Either fix the test-tube to a holder or hang it over the side of the pail, if this is used (Fig. 21). Apply heat by means of a spirit-lamp until all the red powder has disappeared. Do this very carefully at first, by moving the lamp constantly, so that the test-tube may not be overheated at one spot. Bubbles of air or gas will soon be seen to pass through the tube, and up into the receiver over the hole. When all the powder has gone from the bottom of the tube, remove the tube and its connections from the water, and afterward extinguish the flame. What change has taken place in the receiver, and where has the red powder gone to?

NOTE.—In order to insure success in Experiment 3, take care that

all connections are perfectly tight; also use a larger test-tube than you did in Experiment 2.

EXPERIMENT 4.—Put a small piece of chalk on a piece of moistened red litmus-paper. Observe if there is any change in the color of the paper. Afterward heat the same piece of chalk in the flame of a spirit-lamp, and again try it on litmus-paper.

By far the largest number of substances are composed of two or more ingredients. Salt, sugar, vinegar, etc., are compounds, and the chemist is able to tell you just what their composition is. There is no way of finding this out by observation alone, but experiment will help. In Exercise II you discovered that a compound differs from a mixture, and, further on, it appeared that compounds were held together by chemical force or affinity. A compound may be separated into the simple things it was made of, by such forces as heat, light, and chemical action. When this is done we have *decomposed* it, and the process of separation is *analysis*.

EXERCISE XII.

Specific Gravity.

A BALANCE is used in weighing things. The ordinary scales seen in grocers' shops serve the same purpose, and perhaps you know already how to use them. At any rate, you will need a balance or scales for many experiments where accuracy is required. A chemical balance consists of an upright post which supports a beam balanced on a pivot exactly in the center. Pans are suspended at each end of the beam, by means of cords or chains (Fig. 23); when these pans are empty the beam is horizontal, but when anything is put into a pan it goes down and the other one goes up. In addition to the balance we must have *weights.* These are pieces of metal—lead, brass, or iron—not the same everywhere, but fixed upon by the governments of different countries. Here, in the United States, we use weights like those used in England, the starting-point of which was wheat-grains; "twenty-four *grains* of wheat was the weight of a *penny*, and twenty *pennyweights* made an *ounce*, and twelve *ounces* a pound." In apothecaries' weight, "twenty *grains* make one *scruple*, three scruples one *drachm*, eight drachms one *ounce*, twelve ounces one *pound*." The pound, ounce, and grain are the same in this as in troy weight. From time to time changes in these weights have been made, to insure greater accuracy, but it is enough for us to remember that our weights are made to agree with a pattern or standard kept by the Government at Washington.*

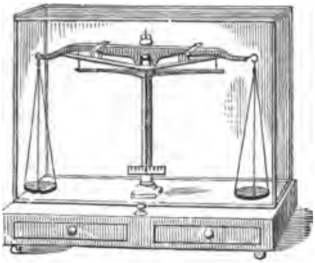

FIG. 23.

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* If the pupil lives in the country, it will be found an interesting exercise to weigh an ounce of wheat-grains, and afterward to count them to see how his grains compare with the present standard. Of course, different conditions of soil, climate, and moisture will cause the grain to vary in weight.

Experiment 1.—Place an ounce-weight in one scale-pan, and slowly add coffee to the other pan until the beam is horizontal. When you have weighed out an ounce of coffee, save it for comparison with other things.

Experiment 2.—Weigh an ounce of fine sand and put it in a heap by the side of the coffee. Which looks the more?

Experiment 3.—Weigh an ounce of corks, and save as before.

Experiment 4.—Weigh an ounce of shot or lead, and finally compare the coffee, sand, corks, and lead.

In weighing by this ordinary method you pay no attention to size or bulk. We say of things weighed without reference to size, that we have found their *absolute* weight.

Experiment 5.—Fill a tumbler up to a certain mark* with water. Place it in one scale-pan and counterbalance it by weights in the other. How much does it weigh?

Pour out the water, dry the tumbler, and fill it with fine sand up to the same mark. Will the weight which counterbalanced the water counterbalance the sand?

Experiment 6.—In the same way as in Experiment 5, find which is heavier, bulk for bulk, water or sawdust, oil or water, milk or water.

Experiment 7.—Fill two tumblers half full of water. Pour a teaspoonful of fine sand into one, and the same quantity of sawdust into the other. Do they behave in the same way?

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* The tumbler can be marked by scratching it with a file. To fill it, place it on a level surface, in order that it may not tip.

EXPERIMENT 8.—Pour out the contents from the tumblers used in Experiment 7, fill again with water, and pour a little milk into one tumbler and a little oil into the other. Try, by stirring the oil into the water, to make it go to the bottom of the tumbler.

Now, you see that *equal bulks* of water and sand are of unequal weight, and the same is true of water and sawdust, water and oil, water and milk. Observe, also, that the things which float in water correspond to those which weigh less than water, while those that sink correspond to those which weigh more than water. When we weigh things, and make an equal bulk of water the standard of comparison, in this way, we obtain *specific weight* or *specific gravity*.

In finding specific gravity, pure water is taken at a certain temperature, and solids and liquids are compared with this standard. A cubic foot of water at 62° Fahr. weighs 1,000 ounces avoirdupois, and if a cubic foot of iron weighs 7,000 ounces its specific gravity is 7. If water up to the mark in the tumbler is taken as 1, and sand up to the same mark requires twice as much weight to counterbalance it, or is twice as heavy, then its specific gravity is 2; if it is three times as heavy, then its specific gravity is 3, and so on.

But we can not find the specific gravity of ordinary solids in this way, because they are of irregular shapes, and do not fit a water-measure as the sand and sawdust did in Experiments 5 and 6. A delicate balance is generally used for the work, having a hook at one end of the scale-beam, of the same weight as the pan at the other end, from which things to be weighed may be suspended.

Experiment 9.—Tie a very fine thread or hair to a gold ring, and fasten this thread to the hook on the scale-beam. Weigh the ring as it hangs in the air, and note its weight; then suspend the ring in a tumbler of water, so that it does not touch the sides or bottom, and is completely under the water, and weigh it again. Does it weigh more in air or in water?

Now find the difference between these two weights, and divide the weight of the ring in air by this difference; the result, or *quotient*, will be the specific gravity of the ring. If the gold is pure, it will be found to weigh about nineteen and a half times as much as the water—that is, its specific gravity is 19½.

Experiment 10.—Find the specific gravity of a piece of lead.

If the pupil does not have a set of suitable weights, Experiments 9 and 10 may be made by weighing the articles in air, with wheat or other grains, and then in water, finding the difference between these weights, and dividing the number of grains-weight in air by this difference.

EXERCISE XIII.

Test-Papers and Test-Solutions.

Provide litmus-paper, cochineal, rhubarb-root or turmeric-root, and purple cabbage. These are distinguished by their color. Litmus is blue coloring matter obtained from certain mosses or lichens found growing on rocks in France and England. Litmus-paper is paper stained by a solution of litmus. Cochineal consists of the bodies of curious little insects which feed upon a species of cactus. This plant was first discovered and cultivated in Mexico; but it is now raised with great care in other tropical countries, because it is the food of these valuable creatures, whose bodies yield a beautiful crimson color called *carmine*. Turmeric and rhubarb roots are yellow. You have, perhaps, made the acquaintance of the latter as medicine, and the former is somewhat like ginger in its qualities.

Buy half an ounce each of turmeric or rhubarb root and cochineal, five cents' worth of litmus-paper, and five cents' worth of tincture of litmus. All these you get at a drug-store.

EXPERIMENT 1.—Soak two or three leaves of purple cabbage in hot water for ten or fifteen minutes. Pour off the purple solution into a bottle, and label it "Purple cabbage test solution." Save this for Exercise XIV.

EXPERIMENT 2.—Put the yellow powder (turmeric or rhubarb) into a bowl. Pour on this one ounce * of water and two ounces of alcohol. Heat this slowly, and filter the tincture thus obtained.

Soak inch-wide strips of filter-paper in the yellow tincture, and hang them over lines of thread to dry in a warm place, where there are no chemical vapors. When the strips of paper are dry, keep them in a tight box away from light and air.

EXPERIMENT 3.—Grind the cochineal to powder. Mix two ounces of alcohol with two of water, and add the powder. Shake the mixture, occasionally, for two days, and pour off the liquid carefully from the sediment.

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* A fluid ounce is equal to eight teaspoonfuls.

Pour a little of this tincture into a saucer and moisten strips of filter-paper in it, as you did before. Dry these and save them; also, bottle and label the rest of the solution.

Experiment 4.—Soak the petals of the iris, violets, or other blue flowers, in a very little warm alcohol. Pour off the alcohol, and press the petals in thin muslin to extract the coloring matter. Dip slips of filter-paper in this tincture, dry them, and see if you can use them in the next exercise as a test for acids and alkalies.

Experiment 5.—Make litmus-paper from the litmus tincture you bought.

Filter-paper, or any other porous paper, when dipped into tinctures of the color-giving substances which we have used, and dried, forms *test-paper*. Litmus test-paper is the most convenient variety, because it will keep indefinitely if it is protected from light and air.

Not only test-papers and test-solutions, but many other things are used by the chemist to show a marked property or quality of a substance. In other words, he tests or "tries" things. The cook tries her bread or cake to see if it is done by running a knitting-needle or fine straw into the loaf; and the workman, in like manner, who taps with his hammer the wheels of the railroad-cars when they stop, applies his test. You will learn, as you proceed, that a great deal of "testing" has to be done in one way and another. We may discover that sugar is sweet, vinegar sour, and water insipid, by merely tasting them; but this is not the surest or best way to learn their qualities. It is not always safe to put things into the mouth: for example, a substance called sugar of lead is sweet, and looks much like common sugar, but this sugar of lead is very poisonous.

In the following exercise the pupil will use the test-solutions and test-papers to "try" things.

EXERCISE XIV.

Acids, Bases, and Neutral Compounds.

The solutions and test-papers already obtained will help you to classify substances. If, for example, a number of things always show the same quality when you apply a test, you will think of them afterward as alike, or as belonging to the same class. The compounds to be tested in this exercise are chiefly common ones, which can be easily obtained, and handled with perfect safety; but, when the strong acids and alkalies are used, follow the directions given below.

Buy at a drug-store small bottles of dilute nitric and sulphuric acids, also a bottle of aqua ammonia. See to it that these have glass stoppers, and that the names of their contents are plainly printed or written on pieces of paper pasted on the outside.

To pour from a bottle, hold it in the right hand, with the proper label next to the palm; remove the stopper with two fingers of the left hand; after pouring the liquid out, catch any adhering drop by touch-it with the stopper, and then replace the stopper. A piece of old muslin, wrapped around a bottle where it is grasped, will catch straggling drops and prevent their getting into the flesh, which they would stain, and perhaps burn.

In using any of the strong acids—that is, nitric, sulphuric, or hydrochloric—have always, near by, powdered chalk or soda; these will destroy or neutralize the acids, as you will discover further on. If, by accident, acid is spilled on your flesh or clothing, scatter this powder over it. It will not remove a stain already made, but it will stop its spreading and continuing to burn.

The alkalies—caustic soda, caustic potash, and ammonia—must also be used with care, for they, too, will burn or eat the flesh. Caustic potash and soda you have had already. They have household uses, and can be obtained at a country store or grocery. Strong vinegar may be used to counteract the effect of them.

Experiment 1.—Pour a little vinegar into a glass, and to this add some of the purple cabbage solution. What change takes place? Secondly, add to the contents of the glass a tiny piece of potash, and note the change.

Experiment 2.—Add a few drops of strong vinegar to a little water in a cup; to an equal quantity of water, in a second cup, add as many drops of ammonia as of acid to the first cup; finally, to these two mixtures add, slowly, a few drops of the cochineal solution. Mark the effect in each case.

Experiment 3.—Dissolve a little piece of caustic soda in a cup, and dip into the solution a strip of the paper stained yellow by the turmeric. What change?

Experiment 4.—Dip a strip of blue litmus-paper into a little weak vinegar. Secondly, wet the same paper in a little soda solution. What changes occur?

By means of the color-tests we can tell the acids from the alkalies; we can also tell if a substance has neither acid nor alkaline qualities, but is *neutral*—that is, having no decided qualities; for the acids will *always* turn blue litmus to red, the alkalies will turn the reds back to blue, and the neutrals produce no change of color. Cochineal, turmeric, and purple cabbage also have their colors changed by alkalies and acids.

Acids are generally sour to the taste, and it is true that all sour things are acids; but some acids are bitter, some are sweet, and some are tasteless. The chemist considers an acid *a compound which will turn a vegetable blue red, and combine with a base.*

The *bases* are opposite compounds which turn the reds back to blue and unite with the acids. Potash, soda, lime, and ammonia are bases; three of them are called alkalies, as you have learned.

EXPERIMENT 5.—Test common molasses by blue litmus-paper. To what class does it belong?

EXPERIMENT 6.—Test saliva by litmus-paper.

EXPERIMENT 7.—Test perspiration by litmus-paper.

EXPERIMENT 8.—Test fresh blood by litmus-paper.

EXPERIMENT 9.—Test the juice of an apple, orange, lemon, or other fruit.

EXPERIMENT 10.—Test the strong acids—sulphuric, nitric, and hydrochloric.

EXPERIMENT 11.—Pour a little pure water into a clean glass and try it by means of the tests; afterward, drop carefully some acid into the water and try it again.

Experiment 12.—Test fresh new milk with litmus-paper; also, test sour milk.

Experiment 13.—Test lime-water.

Experiment 14.—Test salt water.

The list of things given in the above experiments may be greatly extended, and the testing of such as suggest themselves to the mind of the pupil will be just as useful as following the order given; but in all cases carefully note results. Which of the substances tested are found to be acids? which alkalies? which neutrals?

EXERCISE XV.

Salts.

You will continue to use the potash, soda, and ammonia, vinegar and nitric acid. Also provide for use small quantities of fats and oils—as many kinds as you can conveniently get.

Experiment 1.—Pour a little aqua ammonia into a tumbler or wine-glass; test it by litmus-paper. Is it acid or alkaline?

Into a second glass pour some strong vinegar; test this, as before. Is it acid or alkali?

Now pour the vinegar slowly into the glass containing the ammonia. Stir with a glass rod or pipestem and mark the steaming which occurs. Finally, test this mixture with litmus-paper; if red litmus-paper is turned blue, add, drop by drop, strong vinegar; if, on the other hand, blue litmus becomes red, add in the same way aqua ammonia, until the paper is not discolored in the least. What kind of a compound have you now?

EXPERIMENT 2.—Dissolve a piece of caustic potash (used by housekeepers in soap-making) as large as the end of your thumb, in water in a thin kitchen cup; test by litmus-paper. Is it acid or alkaline? If it is alkaline or turns red paper blue, add nitric acid, *very slowly*, until the potash seems to have gone, and you have in its place a *neutral compound. How can you tell when this point has been reached?*

Over a spirit-lamp boil away the water from this neutral compound. When a glass rod, dipped into the cup, shows on cooling a white crust adhering to it, take the cup from the flame and *slowly* dry what remains in the bottom. This solid, you will observe, looks like salt, and indeed it is *a salt*, or *saltpeter*. Taste it.

The neutral compounds, or those which do not change the test-papers, are many of them "*salts*," but you must not make the natural mistake of supposing that they are like common salt, for they are not. The chemist calls compounds formed by the union of acids and bases, *salts*. The acids have qualities opposite to those of the alkalies or bases.

Vinegar is not in the least like soda, but, when certain quantities of these are brought together, the vinegar destroys all the alkaline qualities of the soda, and the soda destroys the acid of the vinegar. In other words, they neutralize each other. The word *neutral* means indifferent, or not taking either side.

Many of our most useful and common things are salts, as, for example, chalk, cream of tartar, limestone, copperas, borax, saltpeter, and soap.

EXPERIMENT 3.—Smear or stain a sheet of paper with butter, tallow, olive-oil, castor-oil, kerosene-oil, oil of lemons, oil of wintergreen, etc. Label each spot with its name, to keep it distinct in your mind, and expose the paper to the atmosphere or to the fire for a few hours. Do all the grease-spots remain?

The most common fats come from animals, but a great number of oils and fats are obtained from plants. The oils which leave a permanent stain on paper are *fixed oils;* those which disappear, are *volatile* or *essential oils.*

EXPERIMENT 4.—Pour two tablespoonfuls of sweet-oil into a bottle, add an equal quantity of water, and shake thoroughly. Can you make them unite? Add a little powdered potash and shake again. What is the result? Test with litmus-paper.

EXPERIMENT 5.—Pour four teaspoonfuls (half an ounce) of castor-oil into a thin earthen bowl, add to this a little hot water, and stir with a glass rod to make them mix. If you do not succeed in this, add a small lump of washing-soda, and boil the whole over a spirit-lamp or the fire. If now the oil has not disappeared, add a little more soda and boil again. Finally, put in a table-spoonful of common salt and allow the liquid to cool. What have you made?

The soap-making, which often goes on in the kitchen, is a chemical process. Soap is a salt—a compound of one of the alkalies with acids contained in fats and oils. Only the fixed oils can be used for this purpose. *Hard* soap is made with potash; *soft* soap, with soda.

EXERCISE XVI.

Oxygen.

A TALLOW candle, small piece of charcoal, iron wire, an ounce of white crystals called chlorate of potash, and half an ounce of black oxide of manganese (powder), will be needed in addition to the pneumatic trough, Florence flask, and glass tubes or clay pipes which you have on hand.

The materials, chlorate of potash and black oxide of manganese, obtained at a drug-store, should be pure. Test them, by taking some of the white crystals, grinding them to powder, and mixing with half as much again of the black powder. Put this mixture into an iron spoon and hold it over some red-hot coals in the kitchen stove, or over the spirit-lamp. If it heats *quietly*, the materials are all right, and can be safely used for the following experiments; but if a slight explosion takes place, it shows that they are impure, and you must *throw them away* and obtain more elsewhere.

EXPERIMENT 1.—Pulverize thoroughly half of the remaining chlorate of potash, and mix it with half of the black oxide of manganese, *carefully heated and dried beforehand.* Put this mixture into a Florence flask or large test-tube (when it is possible to do so, use test-tube instead of flask, because either is liable to be broken by heat, and test-tubes cost less); fit a cork and bent tube to this, or use clay pipes, as explained on page 47; and, finally, when everything else is adjusted, place jars of water on the pneumatic shelf—one must be just over the hole. Light the spirit-lamp or gas-jet, and apply the heat *carefully* (see Fig. 24). It is best to heat the upper portion of the mixture first. In the beginning, the heat will simply expel the air already in the flask; this we do not want to re-collect, but very soon the end of the glass tube may be allowed to pass under the jar filled with water (see Experiment 3, "Decomposition"). Lessen the heat when gas passes over freely, and when one jar has lost its water, move it carefully to another part of the shelf, replacing it by putting a second jar of water over the hole. Continue this until no more gas forms, then remember to take the tube from the water *before* you extinguish the flame. Allow the jars to remain on the shelf for future use.

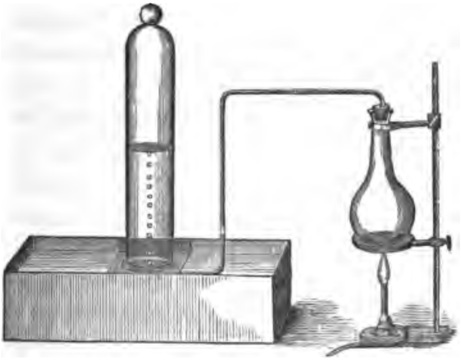

FIG. 24.

If you have managed the experiment well, you have something in these jars which you did not have in the beginning. What is it? what does it resemble?

And when you recall what has happened during the experiment, you will remember that when the lamp was burning under the test-tube, the water gradually left the bottles over the hole, and you saw something which looked like air bubble up and take its place. See if it is air. In order to do this it will be necessary first to contrive some way to get the jar from the shelf without losing the gas. This you may do by slipping a piece of window-glass under a bottle before removing it; then hold the glass firmly against the mouth, slip the bottle from the shelf and turn it right side up, still leaving the glass over its top until you are quite ready to use the gas. The experiments which follow will show you the qualities of this, and perhaps you will conclude that its likeness to air is chiefly in its appearance.

Experiment 2.—Stick an inch of tallow candle into a bent wire as seen in the figure. Light the candle, remove the glass cover from one of the jars used in Experiment 1, and plunge this lighted candle into the jar. What happens? Withdraw the wire, cover the jar, and relight the candle if it has gone out; plunge it now into an empty jar or one which contains *only* common air. Is there any. difference?

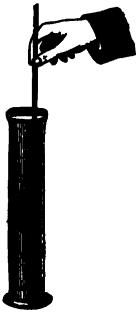

Fig. 25.

Experiment 3. — Again, light the candle used in Experiment 2, hold it above your mouth, and blow up quickly to put out the flame. In this way, you may leave the wick with a spark still glowing on it. If there is one, plunge the wire which holds the candle into the same jar which you used *first* in Experiment 2. Repeat this several times, or until nothing unusual occurs when you introduce the glowing wick.

Experiment 4.—Twist one end of a wire around an old iron thimble (see Fig. 26), and pass the other end through a piece of pasteboard. Put some flowers of sulphur into this thimble-cup; set these on fire, and, when they are burning well, lower the cup and sulphur into a second bottle of gas which you took from the pneumatic shelf. Observe what occurs.

Experiment 5.—Test a little of the gas by holding strips of red and blue litmus-paper in it. Is the paper discolored? In each case, re-cover the jar as soon as the experiment is over, in order to prevent the escape of the remaining gas.

Experiment 6.—Cut a slit in a small pine splinter and stick into this slit a little piece of fine iron wire; light the end of the splinter attached to the wire, and lower it into a fresh bottle of gas* (see Fig. 27). Before doing this, it is well to pour a little clean, dry sand into the jar—enough to well cover the bottom of the jar.

Experiment 7.—Put a little piece of charcoal into the cup used in Experiment 4, heat the charcoal red hot, and afterward lower it into a jar of gas.

Fig. 26.

Experiment 8.—Repeat Experiment 3, "Decomposition," and compare the gas with what you obtained above. Have you any reason to conclude that they are the same?

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* If the supply of gas is exhausted, repeat Experiment 1.

You have discovered by this time that this gas resembles air, in some respects. It is transparent * and has no color, for you can see through it, as if it were glass. It also resembles air in not changing the color of litmus-paper. But toward things that burn, it behaves unlike air; indeed, it seems to *make them* burn. The name of this remarkable gas is *oxygen.* Dr. Priestley discovered it in the year 1774. Of course there had been this gas for ages before he discovered it, since human beings can not live a moment without it; but up to this time no one had separated it from its compounds, and shown its peculiar properties. It is a part of the air, and when any animal is shut up in a limited space it can live only so long as there is a little oxygen there to breathe. In pure oxygen the animal may live longer, but this is very exciting. It makes the heart and lungs work too rapidly. Physicians sometimes give oxygen gas as a remedy in cases where the breathing is impeded. If

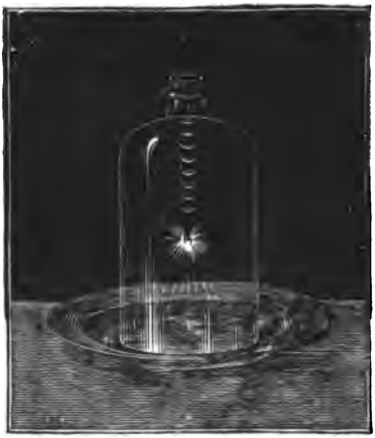

FIG. 27.

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* *Trans* means *through.* When objects allow light to pass freely through them, they are said to be transparent.

you put a mouse or other animal into a large jar filled with this gas, you will see that the effect is to stimulate it. All the vital processes go on much more rapidly at first, but, after living in this state of excitement for a short time, poor mousey falls suddenly dead.

Oxygen is a chemical *element*, or simple substance. By this we mean something which can not be decomposed or separated into anything else, nor can it be made by mixing or combining things. Chemists have found that everything is made up of these elements, of which there are about *seventy*. Some are rare; others very abundant. This one is in almost everything—air, earth, water, even our bodies.

The bright, silver-like liquid which you obtained in a previous exercise (see "Decomposition") was the element *mercury*. When combined with oxygen it makes the powder called red oxide of mercury, and from this compound Dr. Priestley first obtained pure oxygen gas.

For the sake of convenience, the chemist uses a kind of "short-hand" writing. The elements are usually named by the first letter or letters of their English or Latin name; for example, O is the symbol for oxygen, and Fe that for iron (*ferrum*), but Hg is the symbol for mercury.*

Oxygen combines with other elements, as in the case referred to above, forming compounds called *oxides*. A familiar illustration of *oxidation*, or the process by which oxides are formed, is that of iron when exposed to the action of air and moisture. It

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* Latin name for mercury, *hydrargyrum*.

rusts, we say, but iron-rust is only another name for oxide of iron.

EXERCISE XVII.

Plants under the Influence of Sunlight.—Ozone.

Continue the study of oxygen by making some experiments with tender green foliage—pieces broken from almost any window-plant will answer. Also buy at a drug-store a small bottle of sulphuric ether (for further description of this, turn to Exercise XXX).

Experiment 1.—Place a green sprig in a large, wide-mouthed bottle, or, better yet, a glass fruit-can. Fill this can with fresh spring-water, taking care not to leave air-bubbles in it. This can be done by pouring in the water very slowly, so as not to wet the edges; then, after moistening a piece of paper and laying it over the mouth of the bottle, invert it—water, leaves, and all—and place it inverted in a shallow dish of water (see Fig. 28). Expose this to strong sunlight for two hours. Can you then see any change in the appearance of the leaves?

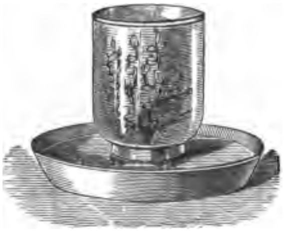

Fig. 28.

Experiment 2.—Repeat Experiment 1, altering it only by putting the bottle containing water and leaves in a dark place. What does this show?

The little bubbles seen upon the leaves (Experiment 1), if they were collected, and then tested by means of a lighted match, would behave just as the gas did which we collected in Experiment 1, Exercise XVI. *It is oxygen gas*, which the leaves under the influence of sunlight have somehow developed. Plants are constantly doing this in daylight. They help to supply us with oxygen, not by decomposing red oxide of mercury, but by decomposing a gas—a compound one (see "Carbonic-Acid Gas") which you will learn something of, by and by.

EXPERIMENT 3.—Pour a little sulphuric ether into a wide-mouthed bottle (keep the ether away from fire, because its vapor is inflammable); heat a glass rod moderately, and hold it in the vapor (see Fig. 29). Do you observe a peculiar odor?

During a thunder-storm, and when an electrical machine is worked rapidly in the open air, a peculiar odor may often be noticed—it is something like the smell of burning sulphur. This odor is due to *ozone*, or oxygen which has become strangely changed in its properties—so changed that we hardly recognize it as the same gas. Indeed, it is very unlike ordinary oxygen, not only in its smell, but in other respects. It tarnishes silver and copper, rusts iron, bleaches bright colors, and destroys the odor of tainted meat.

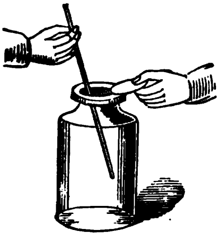

FIG. 29.

It is supposed that ozone is constantly produced in the atmosphere, but that the quantity varies at different times. This is shown by means of a test-paper * which is turned blue by this modified oxygen, the intensity of the color varying on different days.

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* *Ozone test-paper* may be made by dissolving a few grains of a substance called potassium iodide in a little starch paste, and smearing porous paper with this jelly-like solution.

Ozone may be obtained in various ways without the help of electricity, as, for example, by the slow action of the oxygen of the air upon ether (Experiment 3), and also by the action of water upon phosphorus, another element.

EXERCISE XVIII.

Hydrogen.

Get some little pieces of zinc at a tin-shop—the smaller they are, the better. Provide two wide-mouthed bottles—one large enough to hold at least a pint, the other may be smaller—a cork to fit the latter, and a small glass tube.

Draw the tube to a point at one end (see Exercise X), so that its opening will be about as large as a small knitting-needle. Fit the tube to the cork, the cork to the small bottle, and when this is done you have the apparatus for what is called the *philosopher's candle* (Fig. 30).

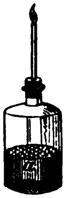

Fig. 30.

Corks may be perforated by means of a cork-borer, if you happen to have one; if not, a hot wire may be passed through, and the hole afterward made smooth by a round file. When a cork is unsound, a little yellow wax, melted and poured over the surface, or a little grease rubbed on with the finger, will make it air-tight, when not exposed to heat.

Experiment 1.—Drop a dozen small pieces of zinc into the bottle described above; pour on these, dilute hydrochloric acid, enough to well cover the zinc, and insert the cork and tube. *Wait three or four minutes*,* then hold a lighted match to the narrowed end of the tube. What effect?

EXPERIMENT 2.—Hold over the "philosopher's candle" a perfectly clear, dry glass bottle that will hold about a pint, and observe what appears on the inside of this bottle.

EXPERIMENT 3.—Hold a fine iron wire in the flame of this new candle; also hold another similar piece of wire in the flame of a common tallow candle. Which becomes the hotter?

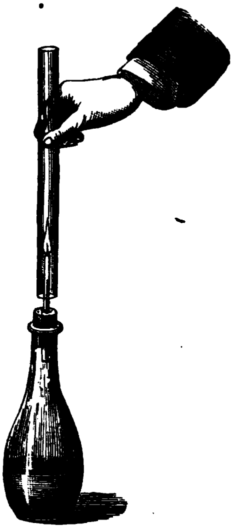

FIG. 31.

EXPERIMENT 4.—Hold a glass tube, open at both ends, over the flame of the philosopher's candle, as seen in Fig. 31. Move this tube slowly up and down. Can you hear anything like musical sounds? Also vary the experiment by using tubes of different lengths and sizes.

The gas which you have seen burning, as it issued from the small tube, is *hydrogen*—another element. This is like oxygen in some of its properties, but very unlike it in others. It burned with a pale-blue flame; oxygen *does not burn*. On the other hand, things such as iron, sulphur, charcoal, etc., burned *in* oxygen, but you could not make them burn in hydrogen gas. The iron wire held in the "philosopher's candle" soon became very hot, for this pale-blue flame gives a great deal of heat. The dry glass held over the flame became dimmed by vapor. This vapor was *water—a compound of oxygen and hydrogen.* Whenever hydrogen burns in the air, it robs the air of its oxygen and combines with it, and the watery vapor may be seen after a while trickling down the sides of a glass held over the flame.

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* This precaution should always be observed, for, if the gas is lighted too soon, there may be a slight explosion.

When two elements unite, the compound formed is usually named by joining the names of these elements, and changing one termination to *ide*, as follows:

Oxygen and hydrogen unite to make oxide of hydrogen (water); oxygen and mercury unite to make oxide of mercury; oxygen and copper unite to make oxide of copper; oxygen and iron unite to make oxide of iron.

You will readily see that the *ygen* of oxygen becomes *ide* in the compound name.

The symbol for hydrogen is H. The short method by which the chemist expresses the composition of these compounds is by writing the symbols of the elements together, thus:

Water, or oxide of hydrogen, is H_2O.*
Oxide of mercury is HgO.
Oxide of copper is CuO.
Oxide of iron is FeO.

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* A numeral placed at the right of a symbol shows the number of volumes taken; thus, H_2O shows that in the composition of water two volumes or measures of hydrogen unite with one of oxygen.

A collection of symbols used as above is a *formula.*

Hydrogen may be obtained in large quantity and collected in bottles or jars by means of the apparatus used for oxygen. Zinc scraps and hydrochloric acid, or iron filings and dilute sulphuric acid, may be used. The gas, when it is liberated from the acid, rises and passes with the air that was in the flask out through the tube, and, when all the air has been driven out, hydrogen gas comes out alone. But whenever this gas mingles with air, an explosive mixture like gunpowder is formed. Experimenting with it implies some danger on this account, and accidents have often occurred. So, if you collect it in quantity, *you must be sure to throw away at least one bottle of the gas* before you save any for use.

On the supposition that you *have* collected a bottle of hydrogen gas (which perhaps you had better not try to do if you are working by yourself and have no teacher to guide you), I will tell you how to prove that it is very light—even lighter than air.

Keep the bottle of hydrogen, mouth down, just as it was collected in the pneumatic trough, until you are ready to use it; then slip it carefully from the shelf into a saucer filled with water. Lift it up from the saucer with the left hand, turning it slightly toward a horizontal position, and with the right hand bring another bottle filled with air to its mouth, as you see in Fig. 32. Hold the bottles in this position for a few seconds, then bring the right-hand bottle, mouth downward, over a flame. The hydrogen gas quickly passed from the lower bottle to the upper one, because it was so light. It took the place of the air, as you will conclude from the fact that something in this upper bottle is burning with a pale-blue flame like that which you saw in the philosopher's candle. And if you turn the bottle which first held the hydrogen right side up, and bring a lighted match to it, you will not find anything here that will burn.

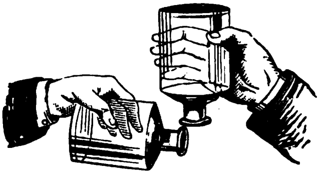

FIG. 32.

Hydrogen will vary in its manner of burning according to the position in which the jar is held. If the mouth is upward, the burning gas, rapidly rising, will burst into a larger flame, sometimes accompanied by a sharp report (see Fig. 33). But when held mouth downward, as seen in Fig. 34, the gas escapes slowly, and burns quietly, because hydrogen is lighter than air, and tends to rise, not to fall.

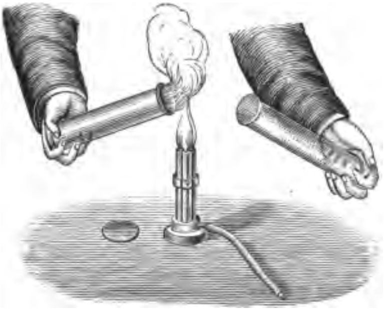

FIG. 33.

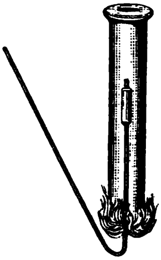

FIG. 34.

Hydrogen is the *lightest substance known*. It is eleven thousand times lighter than water. On account of this property, it has a very curious effect upon sound. In Experiment 4 the musical sounds are produced by the partial putting out and relighting of the flame. These little explosions, occurring one after another at regular intervals, may give a musical note. Formerly hydrogen gas was used for filling balloons; now coal-gas is used. It is said that at certain festivals in Paris, held years ago, balloons were made to represent animals; these, when filled with hydrogen, instantly ascended into the air, but, alas! feet up and bodies down.

EXERCISE XIX.

Water.

The materials for this day's work—a bit of lunar caustic, a handful of plaster of Paris, some strips of bright lead, and soap and water.

Lunar caustic, or nitrate of silver (see "Salts"), has been used in Exercise III; it is prepared by dissolving pure silver in nitric acid; from this solution the small white sticks are finally obtained which you buy at a drug-store. The doctors use it in surgery to eat off diseased flesh, and it is the important ingredient of indelible ink.

Plaster of Paris (sulphate of lime) you may have seen masons use. It is a white powder which was first used for making plaster in Paris. Mix a little of this powder into a paste by adding water, and you will discover that it quickly hardens or "*sets.*" This property makes it a very useful substance in the arts —in the taking of casts, making of cornices, etc.

Strips of lead may be cut from old lead pipe, or they can be had at a tin-shop.

You already know that water, the most abundant and most useful of substances, is a compound of two gases. In every flame, whether that of burning wood, coal, gas, tallow, or hydrogen, one gas is uniting with another to form water. Perhaps you do not see this water, because it may pass into the air as fast as it is formed, and dissolved substances can not be seen, but it can be collected as it forms; you have done this in the last exercise. The chemist can also prove by decomposition that water is a compound of two gases. He combines the gases and gets water; he decomposes water and gets oxygen and hydrogen.

EXPERIMENT 1.—Fill a tumbler two thirds full of clean spring-water, and a second one equally full of rain-water. (For all these experiments collect the *rain*-water in the open country, or as far as possible away from the dust and smoke of dwellings.)

Make some strong soap solution by dissolving white soap in boiling water. Pour a tablespoonful of the solution into each tumbler of water, and mark what happens.

EXPERIMENT 2.—Pour a pint of *spring*-water into a clean white dish of some kind that will bear heat; boil away the water, and notice the inside of the dish. Is it clean now?

Boil away the same quantity of rain-water from a clean dish, and make similar observations. Is there any difference?

Water from natural sources is more or less impure. This can be explained by reference to Exercise IV, "Solution." It has great solvent power, and when it percolates through the soil it dissolves something of whatever it comes in contact with. Distilled water is pure (see "Distillation"), and rain is distilled water, as you will understand, if you think where the rain comes from, and recall the changes through which it passes in its journey from the ocean to the clouds; from these to the earth again. But even rain-water, when it reaches us, may have some slight impurity on account of this same solvent quality by which it has dissolved gases and other impurities from the air.

EXPERIMENT 3.—Fill a quart bottle nearly full of rain-water. Into this put a quarter of a teaspoonful of plaster of Paris. Shake the water and the powder *very thoroughly*. Filter the mixture (see "Filtration"), and compare the filtered water with an equal quantity of rain-water in which no plaster of Paris was put. Do they look alike? Wash your hands first in the filtered water, afterward in the rain-water, using soap in each case. Do they seem alike?

EXPERIMENT 4.—Fill a pint glass fruit-can two thirds full of clear lime-water (see Experiment 2, "Solution"). Blow into this through a glass tube or pipe-stem (Fig. 35) until the clear lime-water has become *first* milky and *afterward* clearer* (see "Carbonic Acid"). Filter this water, which is now limestone or chalk water, and divide it. Test one part

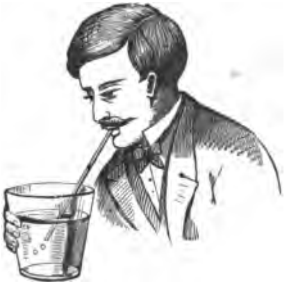

FIG. 35.

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* To render the milky water clear, it will be necessary to blow into it for some time—perhaps ten minutes.

by soap solution, and boil the other part for a few minutes in a glass vessel, and test this second part by soap solution. Is there any difference?

EXPERIMENT 5.—Make some clear chalk-water as in Experiment 4, and add to it a little clear lime-water. What effect? Also add to clear chalk-water some common cooking soda. What effect?

The water of springs, rivers, and lakes is liable to be *hard;* rain-water is *soft.* Water is said to be hard when soap does not readily form soapy foam or lather with it, and soft when the reverse is the case.

EXPERIMENT 6.—Fill two clean tumblers with pure rain-water. Into one of these put a piece of common salt as large as a *pin-head.* Stir well to dissolve the salt, and afterward taste the water which has salt in it. Can you detect the salt by taste?

Now dissolve a piece of lunar caustic in cold water; add to *each* tumbler *three* or *four* drops of this solution. What is the effect?

EXPERIMENT 7.—Fill two tumblers—one with rain-water, or, better still, with distilled water, the other with spring-water—and into each put bright strips of lead. Leave these in the water for twenty-four hours, and observe if there is any difference in the appearance of the water in the two tumblers; also examine the lead strips.

EXPERIMENT 8.—Place an egg in a wide-mouthed glass jar and fill this half full of fresh water (Fig. 36). Does the egg stay where it was put?

Pour some strong brine through a long glass tube down to the bottom of the jar. What happens? and what does the phenomenon show?

The experiments in this exercise are all "tests" of the qualities of water. The differences which you discover, though they may seem slight, are really important. When water has become foul through the decay of plants or animals, we say it has *organic matter* in it; when it is *hard*, it contains dissolved limestone or chalk, and *salt* water or sea-water contains in solution, not only common salt, but small quantities of many similar compounds, such as chloride of potassium, chloride of lime, chloride of magnesium, and chalk, gypsum, etc. The more salt there is in water, the greater its density or specific gravity.

FIG. 36.

All saline substances were once a part of the rocks. "Rain-water falling on the ground and trickling through the soil and over the rocks always finds something which it can dissolve, and which it takes away with it. Thus the sea is constantly having soluble matter carried into it from the land, and it is becoming, though very slowly, more impure.

"Of course, the kind of substance which the rain-water takes up in solution on its road to the sea will depend upon the kind of rock or soil through which it passes, and also, you will say truly, upon the sort of dirt which people living near throw in. Some springs are even more salt than the sea itself, because the water which supplies them flows over a layer or bed of solid salt inside the earth." (Professor Roscoe.)

EXERCISE XX.

Nitrogen.

Experiment 1.—Select a flat cork, smaller than the mouth of a fruit-jar, and hollow it out with a knife. Fasten a small piece of sponge to the cavity by passing a fine iron wire through both cork and sponge. Pour into a shallow dish enough water to float the cork and sponge upon; now saturate the sponge with alcohol, light the alcohol, and instantly cover it with a bell-jar (see Fig. 37), or, better still, with a fruit-jar. If the water from the shallow dish rushes into the jar, add more to take its place. When the alcohol has burned, slip a piece of window-glass under the mouth of the jar, being careful *not to let the water out.* Hold the glass firmly against it, and turn the can right side up, still leaving the glass over its mouth. Why has the water gone into the jar?

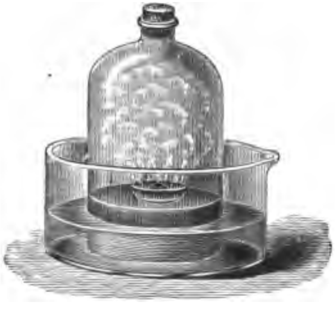

Fig. 37.

Was there anything in the jar which you inverted over the burning alcohol? You answer, "No," or, after thinking a moment, you say, more correctly, "Yes, air." Of course there was air there, and air is a *substance*—a substance free to go anywhere, and occupying all the places where there is not something else already.

Air is a mixture * chiefly of oxygen and another gas called nitrogen. In five gallons of air there is about one gallon of oxygen to four of nitrogen. Air has been collected and examined in many different places and from different heights, but it makes scarcely any difference whether it comes from mountain or valley, from the equator or the Arctic zone, the proportion of oxygen to nitrogen is nearly the same.

Consider, now, what change took place in the jar. "Alcohol burned," you say. Yes, the alcohol burned in the glass, because there was air or oxygen there, but in burning it robbed the air of its oxygen, and left the nitrogen free. When the water rushed into the jar from the plate, it filled only the space which the oxygen had occupied there before. In the upper part of the jar, after the experiment, you have, therefore, *nitrogen gas*. You could obtain this element by burning phosphorus (see page 102) under a glass in the same way, but the use of this substance implies more danger, and it is always safest to let it alone, except under the guidance of a teacher.

EXPERIMENT 2.—Light a candle or splinter, slip off the glass cover from the jar containing nitrogen, and lower the lighted candle into it. What happens? Quickly re cover the jar, to prevent the escape of the gas, and afterward lower the lighted taper again. Also lower a lighted taper into an empty jar. Is the same effect produced?

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* Besides the oxygen and nitrogen, there are always in the atmosphere small quantities of water, of carbonic-acid gas, and ammonia.

EXPERIMENT 3.—Repeat Experiment 1, of this exercise, and place by the side of the jar of nitrogen a second jar filled with oxygen (Exercise XVI). Lower the lighted taper first into the oxygen gas, and afterward into the nitrogen. What difference in the two cases?

Nitrogen, like oxygen and hydrogen, is an *element*. It resembles them in being a gas, in having no color, no odor, and no taste. Its symbol is N. If you should put a living animal into *pure* nitrogen gas, it would die, not because the gas is poisonous, but because, if it is pure, there can be no oxygen with it, and *living things must have oxygen gas to breathe.*

Alone and uncombined, nitrogen is rather uninteresting, and perhaps you wonder of what use it is, since it keeps nothing alive—not even a fire. It has, however, this use: *it dilutes the oxygen.* If air were mostly oxygen, we should soon die, and fires would burn altogether too fast, even for cold weather.

Though animals can not live in pure nitrogen, it is found in their flesh, and it enters largely into the composition of all those substances that rapidly decay. It is also found in ammonia and in many of the most powerful vegetable poisons, such as strychnine, morphine, and quinine. Gunpowder, gun-cotton, dynamite, and nitro-glycerin—all highly explosive compounds—contain nitrogen.

EXERCISE XXI.

Ammonia.

Sal ammoniac, slaked lime, test-papers, blue vitriol, dilute hydrochloric acid, and aqua ammoniæ, have been used in previous experiments; small quantities of these will be needed for this exercise. You probably have them on hand; if not, you know now where to get them.

Experiment 1.—Fill a small Florence flask half full of aqua ammoniæ (dilute), heat the flask over a spirit-lamp, and over the neck of the flask hold a wide-mouthed bottle. When the aqua ammoniæ has boiled for a few moments, slip a piece of *red* litmus-paper under and below the mouth of the bottle. When this turns blue, place the palm of your hand over the mouth, hold it there firmly, and bring the bottle quickly into a bowl of purple-cabbage solution or cochineal solution. What effect?

The red litmus-paper turned blue when the bottle overflowed with a gas called *ammonia*. This is a compound of nitrogen and hydrogen, and the only common one formed by the union of these elements. The chemist writes an abbreviation for the word, thus: NH_3. The number 3, at the right of the letter H, shows that there are three parts of hydrogen to one of nitrogen.

Experiment 2.—Put a fragment of sal ammoniac into a test-tube, heat it over a spirit-lamp, and observe what change takes place.

Experiment 3.—Repeat Experiment 2, "Chemical Affinity." Test the escaping gas by red litmus-paper.

Experiment 4.—Rinse a bottle with dilute hydrochloric acid, then invert it over a bottle holding aqua ammoniæ. What do you see?

Originally this compound was called *spirit of hartshorn*—perhaps you know it by this name. It may be obtained from horns, hoofs, hair, or bones. Experiment 3 illustrates one method of obtaining it at the present time. Sal ammoniac is a compound of ammonia gas and hydrochloric acid (see Experiment 4), and when this solid is mixed with lime, decomposition occurs, and the gas set free may be collected in jars or bottles. Fig. 38 shows the apparatus for this. The ordinary pneumatic trough filled with water can not be used, because ammonia is very soluble in water. A mercury trough takes its place. You learned from Experiment 1 that ammonia is lighter than air. The gas expelled from the boiling aqua ammoniæ filled the inverted bottle by displacing the air or rising to take

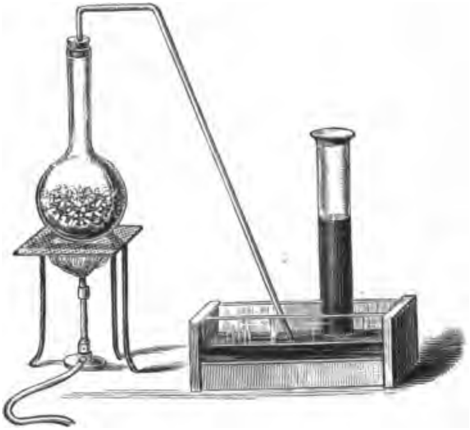

Fig. 38.

its place. This method of collecting gases is known as that of *displacement.* It is because of the lightness of this gas that it diffuses so rapidly in the air. Sometimes it is called *the volatile alkali.* Ammonia is given off whenever animal and vegetable substances decay.

Experiment 5.—Collect, as in Experiment 1, a bottle of ammonia. Light a taper and pass it *up into the bottle.* Does it continue to burn, or does the gas put it out?

Experiment 6.—Dissolve a bit of blue vitriol (sulphate of copper) in a vial or test-tube. Add aqua ammoniæ drop by drop. What effect?

Experiment 7.—Try the effect of aqua ammoniæ on grease-stains, also on stains made by any vegetable acids.

The solution of ammonia in water is the *aqua ammoniæ* (ammonia-water) in common use. In the strongest solution the water has absorbed more than seven hundred times its bulk of the gas. This solution will blister the skin when it touches it. The dilute aqua ammoniæ is strong enough for ordinary purposes, and even this should be used with some care (see acids, bases, etc.).

Aqua ammoniæ is useful in many ways. The doctors make liniment by mixing it with olive-oil, and in the household it is a valuable substance for cleaning clothing, paint, brushes, and indeed all such articles as are not too delicate in color. It acts in cleaning by uniting with oil or grease to form soap (Exercise XV).

EXERCISE XXII.

Nitric Acid.

Buy a small bottle of nitric acid at any drug-store, unless you have already done so, and have it on hand. It is almost colorless when perfectly pure, but yours will very likely have a slight yellow tint on account of some impurity. The old chemists called it *aqua fortis*, which is the Latin term for "strong water." It has a stifling odor, and it is corrosive to the flesh; in using it, follow strictly the directions given (page 57). Also buy two sheets of gold-leaf. You will find it at a picture-frame maker's. This is gold beaten by heavy hammers, for many hours, until it is thinner than the finest muslin. It is estimated that it would take 280,000 of these leaves to make an inch in thickness.

A bit of copperas, a piece of bright sheet-copper, a fresh shaving, and some scraps of white silk, cotton, muslin, white woolen yarn, and beeswax, are also wanted for this exercise.

Experiment 1.—Test nitric acid by litmus-paper and purple-cabbage solution.

Experiment 2.—Fill a wine-glass nearly full of clean water; drop into it five drops of nitric acid. Taste the water without stirring it. Is it sour? Now put a strip of blue litmus-paper into the water, and, if the color changes, observe *where* it changes first. What do you discover from this?

Experiment 3.—Put a clean shaving into nitric acid; also try the effect of the dilute acid on white silk, feathers, muslin, paper, and white woolen yarn. Carefully note the effect in each case.

EXPERIMENT 4.—Pour a little nitric acid, previously diluted with an equal bulk of water, on a fragment of iron, lead, or copper, placed in a porcelain or glass dish. If the metal dissolves, allow the solution to stand for a while, or boil it a little, in order to obtain crystals.

The compounds obtained as above, by the union of nitric acid with metals, or, as in Experiment 2, "Salts," with bases, are called *nitrates*. Thus, we may have nitrate of iron, nitrate of lead, nitrate of copper, or nitrate of potassium (iron nitrate, lead nitrate, copper nitrate, potassium nitrate).

EXPERIMENT 5.—Cover a sheet of bright copper with a very thin coating of beeswax. Write your name with a sharp needle through the wax, and pour over this waxed surface a little nitric acid diluted as in Experiment 4. Wait a few minutes, and then wash off the acid; finally, remove the wax, and observe what you have on the copper.

EXPERIMENT 6.—Put a piece of gold-leaf into a test-tube and pour on it enough nitric acid to cover it. Does the acid dissolve the leaf?

EXPERIMENT 7.—Dissolve a bit of copperas in water; add nitric acid slowly to the solution, or until a dark-brown color appears.* This is a test for nitric acid.

When you have performed the experiments given above, you will not be likely to mistake this acid for ammonia or for air, though in their composition they are somewhat alike. Ammonia is, you know, a compound of nitrogen and hydrogen. In air, the elements oxygen and nitrogen are *mixed* together, but in nitric acid all three of these gaseous elements, oxygen, hydrogen, and nitrogen, have *combined* to form, not a gas, but a heavy, sour, corrosive liquid.

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* If a little strong sulphuric acid is added to the nitric acid, the effect is more marked.

The symbol or abbreviation for nitric acid is HNO_3.

This acid is used in medicine to eat off diseased flesh, for writing or etching on copper and steel, to produce yellow figures on woolen fabrics, and in making the poisonous and explosive compound called *nitro-glycerin*.

The pupil must bear in mind the properties of nitric acid; to distinguish this from sulphuric and hydrochloric acids, studied later.

EXERCISE XXIII.

Carbon.

Experiment 1.—Gradually cover a burning splinter of wood with a wide-mouthed bottle or test-tube. Incline the bottle to one side, as in Fig. 39, to avoid putting out the flame suddenly. The glass will cut off the free supply of air. The charred end of the stick is charcoal.

Experiment 2.—Put a little corn-meal or wheat-flour on a tin plate, heat it over a spirit-lamp, taking care not to let the flour burn. Observe the changes of color, and finally that you have only black charcoal left.

Experiment 3.—Gradually press down a cold plate or piece of porcelain on a burning candle-wick. What collects on the under side of the plate?

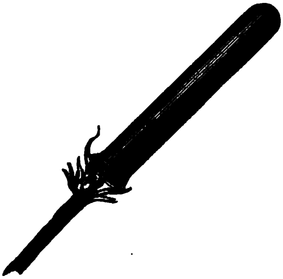

Fig. 39.

Experiment 4.—Put some white sugar into a common kitchen cup, and place the cup on a plate. Pour enough boiling water on the sugar to make a sirup of it, and finally pour into this sirup, carefully, a little sulphuric acid (see Exercise XXX).

Experiment 5.—Make an experiment similar to the above, using blood or a piece of raw meat instead of the sugar-sirup.

In each of the experiments given, you have made *charcoal*, and charcoal is impure *carbon*. This is one of the most abundant of the elements. Half the vegetable kingdom is carbon, which shows why we get it from wood, seeds, flour, and sugar; it is also found in the flesh of animals, in blood, in bones, and in such rocks as limestone and marble. Coal, charcoal, smoke, soot, and bone-black, are all different forms of it which you have seen.

If you take some pieces of dry, hard wood, and put them together by standing them on end, round and round, so as to leave a hole in the middle as you see in the picture, then cover the stack by putting a layer of straw first, and afterward one of dirt or turf around it, leaving some small openings underneath to admit air, also one at the top for lighting the wood and for the escape of gases, you will have what is called a *charcoal-pit*.

Kindle a fire at the top, where you left it uncovered, and, when it gets to burning *well*, cover this opening with straw or dirt. Observe now what is likely to take place. The fire will get no air from the top, but a little will pass up through the small openings at the bottom, and, if the fire had a good start in the beginning, covering it did not put it entirely out, so that it will continue to smoke and smolder, or half burn. Leave the pile in just this state for several days, or even weeks, if it is a large one, then close the openings which admitted air at the bottom. Open the pit when you think the fire has entirely gone out, and you will find, not wood, or even ashes, but *charcoal*.

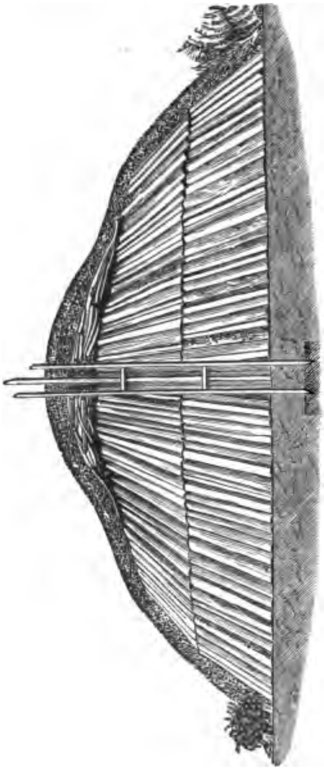

Fig. 40.

This is the usual way of getting it, but, unless you happen to live in the country, it may be inconvenient to make a charcoal-pit; if not, ask at a tin-shop for some pieces of it, *freshly burned.* Also buy some powdered charcoal and some bone-black. The latter, sometimes called *animal charcoal,* is made by heating bones in closed vessels.

Experiment 6.—Weigh a piece of *freshly* made charcoal, and, after leaving *this* piece exposed to the air for a week, weigh it again and compare the two weights. Is there any difference?

Experiment 7.—Wet a paper with aqua ammoniæ, put this paper into a perfectly clean, sweet bottle, and leave it there until the bottle smells strongly of ammonia. Take out the paper and put some powdered charcoal into the bottle. Shake it thoroughly, and smell. What has become of the ammonia?

Experiment 8.—Put four or five teaspoonfuls of charcoal-powder into a bottle; pour foul, stagnant water on it. Shake well, cork the bottle, and leave it for two hours undisturbed. What do you discover?

Experiment 9.—Make a paper filter and put it into a glass funnel or fruit-can (see "Filtration"). Into this paper, scatter several teaspoonfuls of powdered charcoal. Pour water colored by ink or indigo into the filter, and observe, when the liquid passes through, how it looks. Has it lost any color?

Experiment 10.—Prepare a filter as in Experiment 9, but use instead of charcoal-powder the bone-black. Pass through this filter, common dark vinegar, or cochineal solution. Is the effect like that produced by the charcoal filter?

Charcoal is useful in many ways. Its porous structure makes it an excellent absorbent of gases. It has also the power of removing coloring-matters and even disagreeable flavors from liquids. Bone-black (animal charcoal) is much used in sugar-refining; by means of it, dark-brown sugar is converted into the finer white varieties.

The forms of carbon called charcoal are all more or less impure, but in *graphite*, usually called black-lead, and in the brilliant, expensive gem known as the *diamond*, we have pure carbon.

Graphite is the soft substance which you use daily in lead pencils; strictly, they are graphite pencils, or carbon pencils—not lead pencils. You have also seen this used as stove-blacking. It is obtained from mines in England and Siberia, and in this country from California and New York. Fig. 41 shows the form of a graphite crystal.

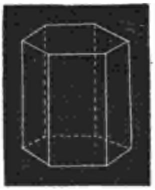

FIG. 41.

The diamond is carbon crystallized (see Figs. 42, 43, and 44). It is the hardest substance known, and the most costly. Diamonds are found in Southern Africa, Brazil, and India. All the other forms of carbon are black; it is only in these carbon crystals that other colors are seen. Diamonds are green, blue, yellow, jet-black, or more frequently white.

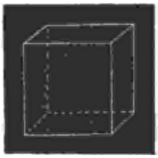

FIG. 42.

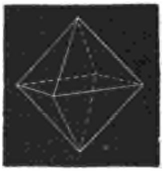

FIG. 43.

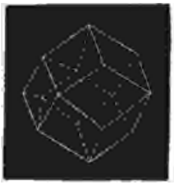

FIG. 44.

On account of its great hardness, this gem is used for cutting glass. The wooden implement, resembling a pencil, which a glazier uses, has a small diamond "set" in its end. Black diamonds are coarser than white ones; this variety is called *carbonado*, and it is used to tip the drills used in rock-boring.

The transparency, hardness, and refractive * power for light of the diamond give it great value as a gem. It is cut by its own powder; nothing else will even scratch it.

A few of the elements occur in different distinct forms or modifications. For example, charcoal is carbon, graphite is carbon, and diamond is carbon. These are called *allotropic* forms. Oxygen, another example of this, occurs in two forms—ordinary oxygen and ozone.

The symbol for carbon is C.

Carbon combines with oxygen, forming oxides, and it unites with hydrogen, giving us a very interesting class of compounds called *hydrocarbons*. These are very numerous, and a large part of chemistry treats only of them.

EXERCISE XXIV.

Carbonic Acid.

EXPERIMENT 1.—Pour two teaspoonfuls of hydrochloric acid into a pint glass jar. Add to this *slowly* common cooking-soda; observe that when you add this there is foaming or *effervescence.* Continue to add soda until the effervescence ceases, then immediately cover the mouth of the jar with a saucer or piece of glass.

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* The power of turning the rays of light from their direct course.

EXPERIMENT 2.—Make an experiment similar to No. 1, but use, instead of cooking-soda, chalk or little pieces of marble.

EXPERIMENT 3.—Remove the cover from one of the jars (Experiments 1 or 2) and lower a burning taper or splinter into it. What is the effect? Also hold some pieces of blue litmus-paper down in the jar. Are they discolored?

The gas which you discover in the jars, after the two first experiments, is not unlike air in color, but quite unlike it in its effects. It is *carbonic-acid gas*—a compound of carbon and oxygen, or an oxide of carbon. There are two oxides of carbon: one, called carbonic oxide, burns with a blue flame, and you often see it playing over the surface of a coal-fire—if it escapes into the atmosphere and is breathed, it may cause headache and dizziness, for it is very poisonous; the other contains twice as much oxygen, and is called carbonic dioxide.* This is the acid gas you are now dealing with.

Its symbol is CO_2.

Perhaps you wonder how this compound comes from what was put into the jars. Think about the experiments. Cooking-soda is carbonate of soda, and chalk or marble is carbonate of lime. These names indicate that the former is a compound of carbonic acid and soda; the latter one of carbonic acid and lime. If we can take away the soda or the lime from either of these salts, we shall have the carbonic acid left free. This is done by using hydrochloric acid, which has a stronger liking or affinity for soda and lime than the acid gas has. The effervescence shows that decomposition is taking place, and the carbonic-acid gas escapes at the same time that the hydrochloric acid forms a new compound with the soda or lime. The carbonic acid in rising pushes out the air and gradually fills the jar.

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* Di means two.

In this case, as in that of oxygen gas, we have not *made* the gas, we have merely separated or set it free from substances with which it was united. But if you should burn charcoal or carbon in any of its forms, in the air or in oxygen gas, as in Experiment 7, Exercise XVI, then you would *make* carbonic-acid gas, for in this case carbon unites directly with oxygen.

Carbonic-acid gas may be obtained in larger quantity by passing it through a bent tube, as you did oxygen gas, and collecting it over the water-trough (see Fig. 45).

The experiments which follow will show some of the properties of this gas.

EXPERIMENT 4.—Light a piece of candle and place it in the bottom of a glass tumbler. Remove the cover from the remaining jar filled with carbonic acid gas, and hold it as if you were pouring something on to the candle flame in the tumbler (see Fig. 46). How do you explain what occurs?

EXPERIMENT 5.—Repeat Experiment 1, and keep the jar well covered until you have made a little dipper by twisting a piece of wire around a small wide-mouthed bottle, so as to make a handle for it, or fasten a string to a small glass. Now hold the bottle or glass by this handle and dip it, *mouth upward,* into the jar (see Fig. 47). Take it out, and put a piece of blue litmus-paper into the bottle or try a lighted match in it. Did you dip up anything except common air?

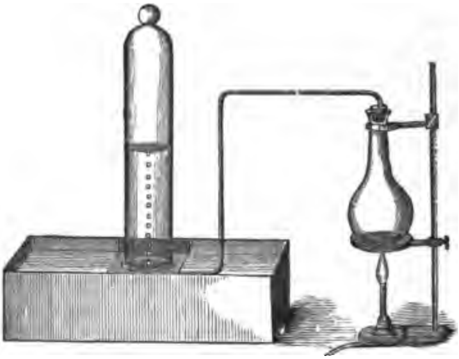

FIG. 45.

EXPERIMENT 6.—Make some soap-suds, and with a clay pipe blow some soap-bubbles into a large empty jar or one containing only air. Also, after repeating Experiment 1, blow soap-bubbles into the carbonic-acid gas. What is the difference?

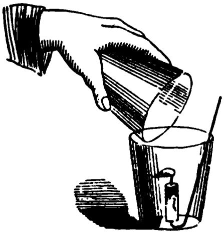

FIG. 46.

EXPERIMENT 7.—Fill a tumbler half full of water, add to this a little litmus solution, enough to give it a slight bluish tinge, and then blow through a glass tube into the colored water. How can you explain what takes place?

Experiment 8.—Blow through a glass tube into an empty bottle for a few minutes. Lower a lighted splinter into the bottle, and notice if there is any change in the brightness of the flame.

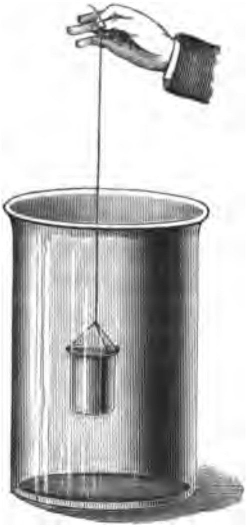

Fig. 47.

Ordinary air which we inhale does not extinguish flame, nor will it turn blue litmus red; but the air we exhale produces these effects. In other words, the experiments we tried show that the air we breathe out has carbonic acid with it. Repeat, or call to mind, Experiment 4, "Water," and explain why the lime-water became milky when you blew into it through a pipe-stem.*

Experiment 9. — Put a piece of limestone as large as an egg into a fire. Heat the stone gradually for half an hour, and, on taking it from the. fire, pour over it a little hydrochloric acid. Does it effervesce as in Experiment 2?

Experiment 10.—Heat as before a piece of limestone, and, instead of acid, pour water over the stone (Experiment 5, "Chemical Affinity").

Limestone which has lost its carbonic acid is called *quicklime.* When water has been poured on to this in sufficient quantity it becomes *slaked* lime.

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* Chalk, limestone, and marble are compounds of carbonic acid and lime.

The word *slaked* means quenched. People slake their thirst; in like manner quicklime combines with a great deal of water, and when it has a certain amount it is satisfied—no more will combine with it. Slaked lime which seems dry is one fourth water.

EXPERIMENT 11.—Mix half a teacupful of molasses with a little water; add to this a tablespoonful of liquid yeast. Fill a test-tube with this mixture, and invert it in the cup containing the rest of the mixture. Allow this to remain in some place where the temperature is from 68° to 70° F., until fermentation takes place. If bubbles of gas collect in the tube, close its mouth by the thumb, and, after removing it from the cup, pour in a little lime-water and shake thoroughly. What has this experiment shown?

EXPERIMENT 12.—Put a little basket of moist, rotten leaves into a fruit-can. Cover the can, and leave it over-night in a warm place. In the morning remove the basket of leaves; pour a little lime-water into the can, and shake thoroughly. Have you reason to think there was any carbonic acid in the can?

Carbonic-acid gas is given off by fermenting and decaying substances. It is this gas in bottled beer, cider, and champagne, which causes the foaming when the corks are removed. Soda-water is really carbonic-acid water. It contains no soda, but a great deal of gas which gives it the delightful sparkling quality.

In kitchen chemistry it is carbonic-acid gas which renders our bread light and porous. Yeast gives it off, and it is gradually disseminated through the dough. Soda and cream of tartar and all the baking-powders produce the same effect.

You will naturally infer that it is a wholesome gas. When *taken into the stomach* it is not harmful, but when taken into the system *by way of the lungs*—that is, breathed—it may cause death. Persons have often suffered from the burning of charcoal in closed rooms, and death has been the result.

But this is not due to any directly poisonous quality of the gas, such as distinguishes the carbonic oxide, but rather to the fact that it takes the place of the life-sustaining oxygen.

There are caves where this gas collects in large quantities. One in Italy is called the *Grotto del Cane.** On the floor of this there is a layer of carbonic-acid gas said to extend higher than a dog's head. A man entering the cave is not affected by it, but dogs when placed on the floor become insensible.

Carbonic-acid gas is liable to accumulate in deep wells and cisterns, and in the unused tunnels of coal-mines. The miners call it "*choke-damp.*" It is dangerous to enter these places without first applying some test which will show the condition of the air. What simple experiment would show if there were much carbonic-acid gas in wells, cisterns, or coal-mines?

Fortunately, the quantity of this gas in the air varies but little.

It is due to the exchange which constantly goes on between plants and animals that this variation is so slight. What one gives, the other takes. Experiments 7 and 8 show that animals exhale (breathe out) carbonic-acid gas, and going back to Exercise XVII,

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* Grotto of the Dog.

Experiment 1, we recall the fact that plants, under the influence of sunlight, yield oxygen gas. Carbonic-acid gas is plant-food; it is taken up by the pores and decomposed into the elements, carbon and oxygen. The plant uses the carbon; it is the chief ingredient of woody fiber, but the life-sustaining oxygen is given back to the air to be used by living creatures, and again exhaled, after it has united with carbon, as carbonic-acid gas. In this manner the wonderful adjustment is kept, and air from the extreme parts of the earth has the same proportion of carbonic-acid gas to the oxygen and nitrogen.

But this is only true when the air is free to be moved by every gust of wind—"when that which is breathed out at the north in the winter may thus go to the south to be breathed in by leaves there, and the sunny southern climes send oxygen for the lungs of those who dwell in the north." When air is shut up the proportion may vary. If many persons are crowded into a small, tight room, the nitrogen of the air here will not change, but the oxygen will become less, and the increased quantity of carbonic-acid gas is plainly shown by dimly-burning lights, and by dullness and drowsiness.

As nitric acid combined with bases forms *nitrates*, in a similar way carbonic acid forms *carbonates*.

EXERCISE XXV.

Combustion.

You are already acquainted to some extent with carbon, oxygen, and hydrogen; in this exercise you continue the study of these, not as single or separated elements, but as they are related to the form of chemical action known as *combustion* or *burning.*

Wood in all its varieties *is composed* of *carbon, oxygen,* and *hydrogen*—that is, of a solid and two gases. In the process of charcoal-making, described on page 90, the slow, smothered fire, by decomposing the wood, drove off the oxygen and hydrogen and left the carbon as unconsumed charcoal. Do not make the mistake of supposing that the chemist can combine oxygen, hydrogen, and carbon so as to get wood; only the growing plant can do this. The carbonic-acid gas (see page 100) obtained from the atmosphere, and the water imbibed by the roots of plants and carried in sap to the growing tissue, are the plant-food. With the help of the sunbeam these compounds are decomposed into oxygen, hydrogen, and carbon, and the plant recombines the carbon, hydrogen, and a part of the oxygen into wood, bark, leaves, flowers, and fruit.

Not only are the separate parts of any single plant developed from these three elements, but all the infinite varieties of vegetable life, from the most delicate moss to the gigantic tree.

Coal, of which there are several kinds used as fuel, is chiefly carbon. The soft coal, or cannel coal, contains hydrogen in addition to the carbon. The fats, oils, sugar, starch, alcohol, turpentine, and all the common things which give us heat and light, are made of carbon, oxygen, and hydrogen in different proportions.

Matches are little pieces of soft wood, the ends of which have been dipped, first, into sulphur, and then into a paste made of phosphorus, gum-arabic, and water, and afterward dried.

Phosphorus is an *element* never found by itself in nature, but obtained from bone-ashes. It is soft like wax, and, when pure, transparent and almost colorless. It looks as harmless as a piece of cheese, but in reality it is dangerous to touch or handle, because, when warmed, if only slightly, in the air, phosphorus is liable to take fire, and burns from it heal with great difficulty. It takes fire at 150° in the air. Hence, chemists keep it under water and even cut it under water. Its symbol is P.

Experiment 1.—Light a match. How do you do it? What effect is always produced when two things are rubbed together?

Experiment 2.—Kindle a wood-fire in a fire-place or grate. Note how you do it: is it by striking pieces of wood together?

Experiment 3.—Make a coal-fire. How is this done, and what difference do you discover between the burning of the wood and the coal? What phenomena are the same whether you burn matches, wood, or coal?

Experiment 4.—Cover a bed of glowing coals with ashes, leave it undisturbed for eight or nine hours, then uncover it. Has the fire entirely gone out? Can you rekindle it by blowing upon it? Could you rekindle a fire by blowing carbonic-acid gas on the coals?

EXPERIMENT 5.—Put a burning candle down into a narrow-necked bottle. How long does it continue to burn *well?*

EXPERIMENT 6.—Remove the candle from the bottle (Experiment 5), and pour a little clear lime-water into it, cork, and gently shake the bottle (see "Carbonic Acid").

Also, pour an equal quantity of lime-water into a bottle in which no candle has been burned, cork as before, and, after shaking, compare the water in the two bottles. If there is any milky appearance in either case, add a few drops of vinegar. What appearance now?

EXPERIMENT 7.—Light a candle and hold *over it* a *perfectly dry cold* glass tumbler (see Fig. 48). Does the glass remain clear?

The kindling of a fire, or the beginning of active combustion, is *ignition.*

When this chemical action or burning has begun, if oxygen is freely supplied, all compounds containing carbon and hydrogen will continue to unite with it, heat and light will result, and carbonic-acid gas and water will be formed (Experiments 6 and 7). Limit the supply of air or oxygen, and the fire goes out (Experiments 4 and 5).

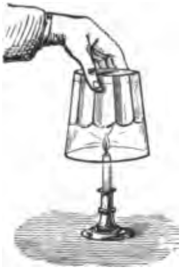

FIG. 48.

Oxygen being necessary to all ordinary burning, it is called a *supporter of combustion*, and such things as burn in it are *combustibles*.

There are other supporters of combustion, as you will learn farther on (page 117).

Many combustible bodies contain oxygen in addition to carbon and hydrogen. Such as contain little or no oxygen burn with a dull, smoky flame, those having a larger proportion of it burn more brightly, and those very rich in oxygen give little light, but much heat.

Experiment 8.—Put a little sugar into a saucer or something that will bear the heat of a spirit-lamp. Heat it slowly at first, gradually raising the temperature until the sugar is burned. Is there much or little oxygen in sugar? Try the same experiment with starch.

Experiment 9.—Burn two or three sticks of dry maple-wood—also burn an equal number of pine sticks. Note the difference in the flames, also in the coals left.

Experiment 10.—Repeat Experiment 8, using rosin instead of sugar. Do you think that this contains any oxygen?

Experiment 11.—Pour a tablespoonful of alcohol into a saucer, and set fire to it.

Experiment 12.—Dip a piece of blotting-paper into turpentine and set fire to the paper; but be careful in all these cases not to ignite your clothing. Do you think that turpentine contains more oxygen than alcohol does?

It must be quite plain now that combustion is a chemical process; but when the wood, coal, candle, etc., have disappeared, where have they gone to? We say, "they have burned up." This, however, does not tell the whole story. Something is left. What? "Carbonic-acid gas, water, and most likely smoke or soot." It is no more true that the elements have been lost, than that the lump of sugar dissolved in the cup of tea is lost. The form has changed but nothing has gone.

When wood is exposed to air and moisture it is liable to *decay*. This decay is only the gradual union of the wood with oxygen. It is *slow combustion*. The rotten log of forest timber has undergone the same change as the one which was first split into fire-wood and afterward burned on the hearth; the only difference being that one burned in a few hours, the other in a few years.

Sometimes oxygen combines slowly with substances at first, but gradually the heat increases and slow combustion becomes more and more rapid, until finally they take fire and are quickly consumed. When cotton used for wiping machinery has become soaked with oil, and is thrown aside in heaps, it is liable, after a time, to suddenly burst into flames. This ignition from slow combustion is called *spontaneous combustion*.

EXERCISE XXVI.

Flame.

Experiment 1. — Light a candle having a large wick; protect the flame from all draughts which may come from opening and shutting doors and windows, and quick movements of all kinds. When the candle is burning well, and with a *large* and *regular-shaped flame*, hold before it a piece of pasteboard cut into the shape of the flame. If this pasteboard screen is too large, keep trimming it down until it *just hides* from the eye the luminous part of the flame when it is held close to it. Now look for a non-luminous section outside of the light one. Can you see it?

Experiment 2.—Hold a match for a moment horizontally across a candle-flame, *just above the wick.* Observe that the match is burned at the sides, not in the middle. What does this show?

Also thrust the head of a match into the middle of the flame, and then withdraw it. Can you do this without igniting it?

Experiment 3.—Press a piece of glazed note-paper quickly down into the candle-flame, until it almost touches the wick. Avoid draughts, even such as might come from talking. Remove the paper before it takes fire. Where is the paper scorched? How do you account for its appearance?

A candle-flame consists of three parts (see Fig. 49)—that just above the wick is dark and gives no light; this is surrounded by a light-giving, cone-shaped section, and outside of this there is a cloudy appearance, not as distinctly visible as the others, but just as much a part of the flame. You should carefully observe the candle-flame until you can detect these parts. They pass into each other gradually, not by clearly marked lines. Experiments which follow will show the nature of these sections.

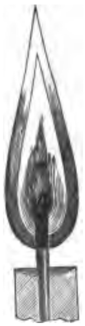

Fig. 49.

EXPERIMENT 4.—Make observations similar to those suggested in Experiment 1 on a common gas-flame. Do the parts of this correspond to those of the candle-flame?

The gas used to light cities and large towns is made at gas-works from coal. This is intensely heated in large retorts or ovens. Heat decomposes it, and impure gas is liberated, together with water and tar. The gas is afterward purified, and then collected in an immense reservoir, called a *gasometer;* from here it is carried through pipes to streets and dwellings, and we see it in the common gas-flame (see Fig. 50.)

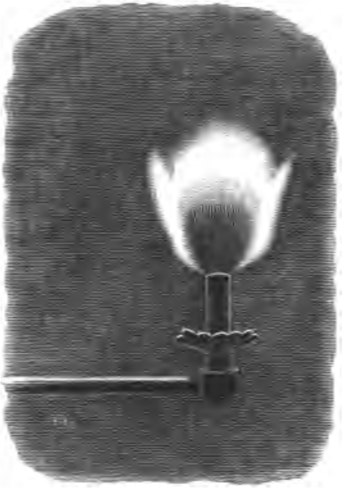

FIG. 50.

Lamps and candles are small gas-factories which make gas and also burn it. The materials for it are in the tallow and the oil. Watch a burning candle and you will, perhaps, get an idea of how the work goes on here. The heat of the burning wick gradually melts the tallow, and this melted tallow is carried up the loosely twisted fibers of the wick by what is called *capillary attraction.* This kind of attraction was discovered by putting the ends of small tubes into water, when the liquid was seen to gradually go up them, and the smaller the tubes, the higher did the water climb. *Capillus* is the Latin word for hair; hence, small, hair-like tubes are called *capillary* tubes, and the attraction is *capillary attraction.* When the melted tallow reaches the flame, it is decomposed into substances much the same as come from the gas-works—that is, hydrogen gas and carbon.

EXPERIMENT 5.—Light the spirit-lamp. Hold a small wire across the upper part of the flame for a minute or two. Where does it become red-hot first? Observe this flame as you did the candle-flame. How many parts has it?

EXPERIMENT 6.—Thrust the head of a match first into the interior of an alcohol-flame, and afterward hold it for an instant in the outer section. Is this flame hotter next to the wick, a little way above it, or on the outside?

EXPERIMENT 7.—Lower a piece of fine wire gauze* on to a flame. Examine the flame by looking at it from above through the gauze. Can you see the inner section? (See Fig. 51.)

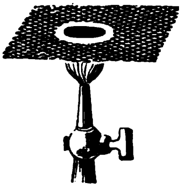

FIG 51.

EXPERIMENT 8.—Hold a small glass tube, five or six inches long, and having a diameter of from one third to one half an inch, obliquely in a candle-flame so that its lower end will reach to the dark section *just above the wick* (Fig. 52). After waiting a minute or two, present a lighted match to the other end. Be careful to avoid draughts and to hold the tube steady. If you make no discovery at first, try again.

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* Get wire gauze of a hardware dealer; if he does not happen to have it, perhaps he will obtain it for you.

Experiment 9.—Hold a very cold, bright knife-blade in a candle-flame for a minute or two. Then withdraw it and examine it for traces of soot. In which part of the flame did the knife become smoky?

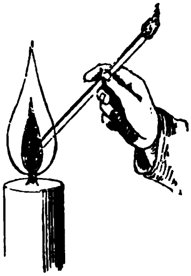

Fig. 52.

Experiments 5 and 6 have shown you that the flame sections are not all uniformly heated—the flame is hottest near its margins.

The dark section which is seen by looking down through the wire gauze upon the flame *consists of unburned gas* (Experiment 7, see Fig. 51).

In the light-giving cone *imperfect* combustion is going on; the hydrogen burns briskly, and heats the carbon to a white heat. Glowing particles, thus heated and beginning to burn, give brightness to the flame. They may be obtained as soot (Experiment 9), or pass to the outer section, where they meet plenty of oxygen, and combining with it form carbonic-acid gas. In this less clearly defined zone, *combustion* or *burning is complete.*

Experiment 10.—Wind a piece of fine copper wire eight or ten times around a lead-pencil (Fig. 53). Remove the coil thus formed, and gently lower it, as if it were an extinguisher, over a burning candle-wick. What happens? Can you explain?

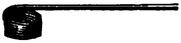

Fig. 53.

Experiment 11.—Press the piece of wire gauze, used in Experiment 7, on a candle-flame (Fig. 54), or, better still, on a burning gas-jet. Does the flame pass through the wire meshes? Why?

Experiment 12.—If the flame has not passed through the gauze, see if you can light the gas on the upper side. If you can light it, gradually raise the screen from the flame. Does the lighted gas move with it?

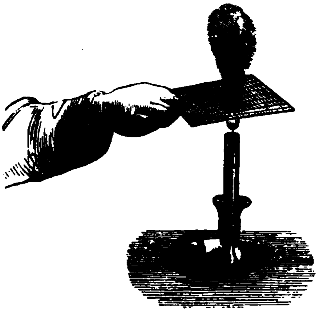

Fig. 54.

Experiment 13.—Place a piece of camphor-gum on the sheet of wire gauze, and lower it as before over the flame. Set fire to the gum and observe what takes place on the under side of the gauze.

Since a certain definite degree of heat is necessary for the burning of a combustible substance, it follows that if the temperature be lowered below that point the flame will go out. A familiar illustration of this is seen in the "blowing out" of a candle-flame. The same principle is shown by Experiments 10 and 11. The wire and the gauze cool the flame below the point required for active combustion. In the case of the gauze the flame looks crushed by it, not extinguished, and the gas passes freely through to the other side, where it can be ignited, as you have already discovered.

In the process of mining for coal, which is often done deep in the earth, explosive gases are met with. Formerly these were liable to be set on fire or ex-

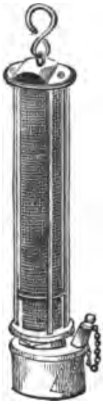

FIG. 55.

ploded by the lamp or candle carried by the miners, and thus horrible accidents occurred. An Englishman, Sir Humphry Davy, made use of the fact that wire gauze, by conducting away the heat, lowers the temperature of the flame, and thus prevents the gas from burning on its upper side. He constructed a lamp, known as the "Davy Safety Lamp," the peculiarity of which is a gauze cover which may be screwed on to the lighted lamp. The flame shut up in this wire cage does not pass outward to kindle the gas of the coal-mines. This gas requires a high temperature for its ignition. Fig. 55 is a picture of this lamp, which has been the means of saving thousands of valuable lives, for an explosion can not occur if the lamp is properly used.

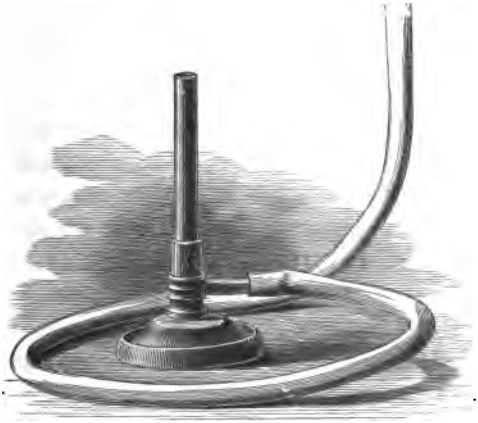

FIG. 56.

The brightness of any flame depends upon the presence of solid matter in it, heated to the glowing point, though not consumed. But when there is sufficient oxygen to burn all the elements, the solid carbon as well as the gases, then the flame is intensely hot, but not luminous. This is done in the Bunsen burner, mentioned in Exercise III. It consists of a tube, at the base of which several small holes admit a plentiful supply of air. A second tube opens into it from the bottom and admits the coal-gas (see Fig. 56). The two gases thus become thoroughly mingled before reaching the top, where the gas is lighted. This flame emits but little light, but if the air-holes are closed it becomes the ordinary luminous flame.

EXERCISE XXVII.

Iodine.

In the exercise on "Sublimation" you used some bright metallic scraps or scales which on account of their luster and color might easily have been mistaken for black-lead. It was the *element iodine*, one of a class of substances having somewhat similar properties, and three of which, iodine, chlorine, and bromine, are obtained from sea-water, or the productions of the sea. Their symbols are I, Cl, and Br, and you can easily associate the names of these elements together in your mind by remembering that they all end in *ine*.

Bromine is a dark-red liquid, with an intensely suffocating odor. It is like mercury in being liquid at ordinary temperatures.

The ashes of burnt sea-weed (kelp) are the source of iodine. It is an interesting substance, and what was left from the previous exercise will be enough to show its peculiar properties. Be careful in using it to avoid inhaling much of its vapor.

EXPERIMENT 1.—Smell iodine, and observe the color and shape of the scales. What is its odor like?

EXPERIMENT 2.—Put a little iodine into water. Will it dissolve? * Also see if it will dissolve in alcohol. If it dissolves in alcohol, what shall we call the solution?

EXPERIMENT 3.—Wrap a few scales in a piece of white muslin. After half an hour unwrap them, and observe the effect upon the muslin.

EXPERIMENT 4.—Put some iodine into a pint glass jar, and place this in a sand-bath (see page 42) over the spirit-lamp. Light the lamp, and, when the jar becomes full of violet-colored fumes, cover its mouth with a piece of window-glass and remove the lamp.

Slip the glass from the jar and lower a lighted taper into it. What effect?

EXPERIMENT 5.—Dissolve a little starch, by moistening it first in cold water and afterward pouring boiling water on it; test this starch-paste, both hot and cold, by adding to each part a drop of *tincture of iodine.*†

EXPERIMENT 6.—Pour some of the blue solution obtained in Experiment 5 into a Florence flask; cork the flask and heat it over a spirit-lamp. When it is just on the point of boiling, pour cold water on the flask.

---

* Save dissolved iodine for future use.

† Iodine is the test for starch, and starch is the test for iodine.

Experiment 7.—Slice a potato and an apple, and on their freshly cut surfaces drop a little tincture of iodine; also try the effect of the tincture on a piece of wheat-bread. What does this experiment show?

Iodine unites with other elements, forming *iodides*. Iodide of silver is used in photography, iodide of potassium and iodide of mercury in medicine.

EXERCISE XXVIII.

Chlorine.

Chloride of lime is especially useful in the household. It comes in half-pound or pound packages, and these can easily be obtained at a country store or of druggists. Provide a package of this, and have it in readiness, in addition to sulphuric and hydrochloric acids, some brightly colored cotton scraps, red flowers, litmus-paper, etc.

Experiment 1.—Pour into a wide-mouthed pint bottle (a fruit-jar will do very well) two tablespoonfuls of sulphuric acid; add to this, by degrees, two and a quarter tablespoonfuls of bleaching-powder (chloride of lime). After putting in the powder, always cover the jars with pieces of window-glass to prevent the escape of gas. Finally, observe the color of the gas formed, by comparing the bottle in which you put the acid and lime with an empty one of the same size and shape. Set aside the covered jar for use.

The greenish-yellow colored gas obtained as above is *chlorine.* It is a heavy gas, two and a half times heavier than air, with a suffocating bad smell, and it may make you cough. When a little is mixed with a good deal of air it does no harm to breathe it, but inhaled, undiluted, it might cause death. Hence, in collecting it, and in experimenting with it, keep the vessels covered except when it becomes necessary to uncover them, and always have a window open in the room. In case of any accident, by which a large quantity of chlorine gas escapes and is breathed, the best antidote is to go immediately into the open air and walk briskly.

Bleaching-powder is a compound of chlorine and lime. Sulphuric acid has a strong affinity for lime, so strong that it robs the bleaching-powder of it, and thus sets free the chlorine gas.

EXPERIMENT 2.—Hang a piece of brightly colored calico in one of the jars containing chlorine; re-cover the jar and leave it for one hour; then examine the calico for change of color.

Afterward *moisten* a similar strip and treat it as before. Is the effect the same?

EXPERIMENT 3.—Moisten a bright rose or geranium flower, and suspend it in a jar of chlorine.

EXPERIMENT 4.—Try the effect of chlorine upon a piece of paper written over with ink; also try the effect of it upon printed paper.

EXPERIMENT 5.—What effect has it cn litmus-paper?

Fifty or sixty years ago all linen and cotton materials were bleached by long exposure to sunlight and moisture; now this is done much more quickly by means of chloride of lime. It is really the chlorine which bleaches. Water is poured on the powder and the mixture is allowed to settle; afterward the clear liquid is poured off, and the articles to be bleached are soaked in the solution. They are usually first moistened by vinegar or other weak acid.

Enough chlorine gas for most simple experiments may be obtained by the method already given, but for some purposes this will not do. The ordinary method is to decompose common salt or hydrochloric acid; both these contain chlorine. Fig. 57 shows the apparatus used.

Experiment 6.—Mix half an ounce each of common salt and black oxide of manganese; put this mixture into a flask provided with such a tube as you see in the picture. Add to this one ounce of sulphuric acid, previously diluted by half as much water. Apply heat gently, and observe that soon a greenish-yellow gas begins to collect in the receiver, where it will gradually displace the air, because it is much heavier than air.

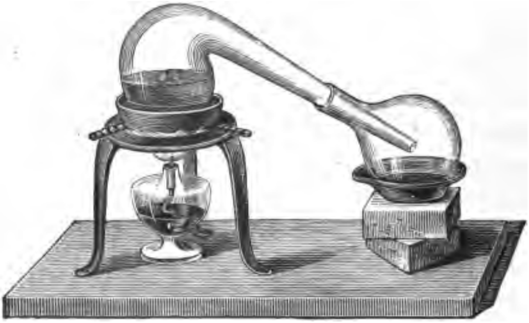

Fig. 57.

EXPERIMENT 7.—Light a candle, and plunge it into a jar of chlorine gas. Is it unlike oxygen in its effect upon flame?

EXPERIMENT 8.—Moisten a piece of paper with *warm* turpentine, and suspend it in another vessel of chlorine gas (Fig. 58). What effect?

Chlorine gas was discovered the same year that oxygen was. You have seen that they are both supporters of combustion, which simply means that they have strong chemical affinities, and readily unite with some elements. But chlorine can not be safely breathed, and, although it is useful for bleaching and disinfecting purposes, human beings might comfortably live without the gas, when uncombined, but this would hardly be true of one compound which it forms with the element sodium.*

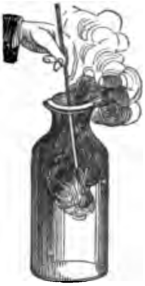

FIG. 58.

As oxygen united with other elements forms oxides (page 67), so chlorine united with certain elements forms compounds called *chlorides*. One of these is *chloride of sodium* or common salt. This useful and necessary substance is found as a natural deposit in the earth. The most noted salt-mines are in England, Poland, and Germany. Salt is also obtained from the water of lakes and springs in the United States. Brine from these sources is pumped by machinery and carried to large boilers, from which the water is driven off by heat. Sometimes the water is expelled by the slower process of evaporating it from shallow pans exposed to the sun. Salt is also obtained from sea-water.

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* Sodium is a soft, white metal, an element which must be kept under naphtha.

Chlorine has a very strong affinity for hydrogen. Indeed, its power to bleach and to destroy bad odors is due to its tendency to seize this gas wherever it finds it. You discovered by experimenting with chlorine gas that the moistened things were the ones which lost their color, and this was due to the fact that moisture or water contains hydrogen. Ordinary combustible substances also contain hydrogen.

It is very remarkable, if indeed one thing is more wonderful than another in the domain of science, that chlorine and hydrogen, though having this strong liking for each other, may be kept in a dark place, when they are mixed together, for any length of time without uniting; but bring the mixture to the sunlight, and a union quickly occurs. A new gas is formed, entirely unlike the others — this is *hydrochloric-acid* gas. Its symbol is HCl. Hydrochloric acid, also called muriatic acid, is a solution of the gas in water. You have used it, and know something of its properties. It is a powerful acid, and an important one in the arts and to the chemist.

EXPERIMENT 9.—Repeat Experiment 6, "Nitric Acid"; also put a second piece of gold-leaf into another test-tube and cover it with hydrochloric acid. Does the gold-leaf dissolve in either acid?

EXPERIMENT 10.—Mix the contents of the two tubes together and warm slightly. What effect?

A mixture of hydrochloric acid and nitric acid is called *aqua regia*, or royal water.

EXERCISE XXIX.

Sulphur.

THE familiar substance called sulphur is an element. It is found chiefly in volcanic neighborhoods. Etna, on the island of Sicily, and Southern Italy afford us much of our supply. But the native sulphur from these regions is apt to be mixed with dirt and other impurities. We generally see the sulphur only after it has been freed from these, and melted into sticks about as large round as a broom-handle, called *roll-sulphur* (brimstone), or in the fine powder known as *flowers of sulphur*, obtained by sublimation. In the last form you have made its acquaintance in Exercise I. Obtain also a piece of roll-sulphur for experiments. This element is found in animal substances, such as hair and eggs, and in certain plants which have sharp, pungent flavors — mustard, horse-radish, and garlic.

Sulphur is used in large quantities for bleaching silk and woolen fabrics, in the manufacture of gunpowder, sulphuric acid, and matches, and in the household it is a common domestic medicine.

The symbol for sulphur is S.

EXPERIMENT 1.—Taste and smell a bit of roll-sulphur, also some of the flowers. What do you say of their flavor?

EXPERIMENT 2.—Dissolve some flowers of sulphur in hot or cold water. Do things which do not dissolve have taste or smell?

EXPERIMENT 3.—Dissolve some flowers of sulphur in oil of turpentine; * shake the mixture occasionally until the powder has dissolved, then pour the solution into a shallow dish, and allow evaporation to go on slowly. If crystals form, look at them carefully. Which form are they like? (Fig. 59.)

EXPERIMENT 4.—Hold a piece of roll-sulphur in your hand near your ear for a few moments, and listen for a peculiar crackling sound; also hold it over the flame of a spirit-lamp. How do you explain the phenomenon?

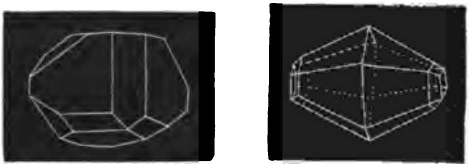

FIG. 59.

EXPERIMENT 5.—Heat an ounce of sulphur flowers, or bits of roll-sulphur, in a kitchen cup or crucible. If the cup is used, and it is a thick one, regulate the heat by the sand-bath. How is sulphur affected by heat?

EXPERIMENT 6.—Pour about a third of the melted sulphur obtained, Experiment 5, into cold water, and return the cup to the spirit-lamp or other heating-place. Take the sulphur from the cold water, dry it, and drop the lump into the cup containing the liquid sulphur. Observe if it behaves in the same way that ice does when it is dropped into water.

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* A compound called carbon disulphide is the best solvent for sulphur.

Experiment 7.—Melt in a cup or crucible, as before, some sulphur, and allow it to cool until a crust forms on its surface. Pierce this crust with a glass rod or small stick, and pour the remaining liquid out. Afterward break the cup to see the crystal cavity within (Fig. 60).

Experiment 8. — Melt a table-spoonful of sulphur in a test-tube. Prolong the heating until it becomes thick and dark like molasses. In this state, pour it into cold water, and try to mold it into some form (Fig. 61).

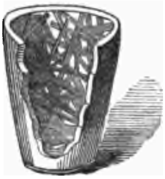
Fig. 60.

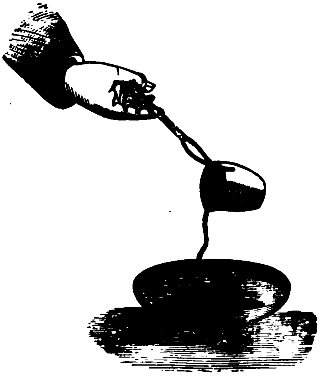
Fig. 61.

Note.—The success of Experiment 8 will depend upon its being sufficiently heated, and, since sulphur at a high temperature takes fire if exposed to the air, care should be taken in this experiment to cover it. Sulphur melts at 232° F., becomes like molasses at between 430° and 480° F., and again liquid at 792° F.

Sulphur is another allotropic element. It crystallizes in two distinct forms, and hence it is said to be *dimorphous* (Experiments 3 and 7); it is also seen in a plastic state, when it resembles India-rubber (Experiment 8), and is said to be *amorphous*. See "Crystallization."

Experiment 9.—Heat a little sulphur in an iron spoon over a spirit-lamp. Observe the color of the flame and the odor. Also hold a piece of blue litmus-paper in the smoke.

Experiment 10.—Boil a little sulphur in a dry test-tube; then warm a piece of copper wire or foil in the lamp-flame, and by means of a pair of pincers drop it into the melted sulphur. Observe the color of the burning copper.

Experiment 11.—Put a few flowers of sulphur into a wide-mouthed bottle, or into a little dish placed under a glass receiver. Set fire to the sulphur, and either hang a bright red rose, by a thread, in the bottle and cork it, or place bright flowers under the glass, over the burning sulphur, as seen in Fig. 62. What change takes place in the flower? Afterward wash the rose in water containing a little sulphuric acid.

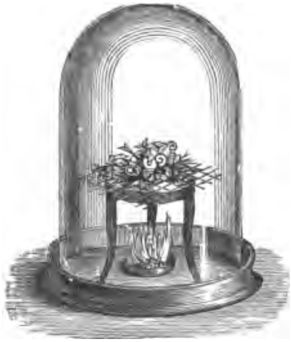

Fig. 62.

Experiment 12.—Put a clean, bright silver spoon into a freshly-boiled egg. Leave the spoon in the egg for a short time. What effect?

The peculiar and unpleasant odor observed in burning sulphur, Experiment 9, may lead you to draw a conclusion quite different from what you did in Experiment 1; but bear in mind that, when things burn in air or in oxygen gas, *new compounds* are formed. It is not sulphur which you smell, but *sulphur dioxide* which escapes as smoke; see Experiment 2, "Chemical Compounds." If you light a match, you will get the same stifling, disagreeable odor, because the same compound is formed. The symbol for this compound is SO_2.

Sulphur dioxide is used in bleaching straw, feathers, silk, and wool, but it is unlike chlorine in its effects. The color of the flower (Experiment 11) was restored by the use of dilute sulphuric acid; in the bleaching by chlorine the color is actually destroyed.

This compound is a useful disinfectant. It destroys unhealthful germs which may cause disease.

Sulphur not only combines with oxygen but with hydrogen, and with the elements called *metals*. When it combines with the latter, the compounds are *sulphides*. Thus, in Experiment 4, "Chemical Compounds," sulphide of iron was formed, and the silver spoon was discolored in Experiment 12 by the formation of a sulphide of silver.

EXERCISE XXX.

Sulphuric Acid.

SULPHUR combines with oxygen and hydrogen to form many different acids, but only one is of great importance. This is *sulphuric* acid, the *king of acids*, not only the strongest but the most useful one. It is used in making all the other strong acids, in bleaching, dyeing, and calico-printing, and in refining fats and oils. Indeed, the chemist and the manufacturer could not well get along without it. A million tons of it are said to be used every year.

Sulphur dioxide, SO_2, when passed into cold water is absorbed, and the solution is *sulphurous* acid, and sulphuric acid is made from this simply by the addition of more oxygen. This needed oxygen is obtained from nitric acid, which, as you learned in Exercise XXII, contains it.

The abbreviation for sulphuric acid is $H_2 SO_4$.

The strongest sulphuric acid is that made at Nordhausen, Saxony, and it takes its name from this place. Originally, it was made from green vitriol, and hence was called "*oil of vitriol.*" This strongest acid is a thick, colorless, oily liquid, not very safe to use. It is carried from place to place in large glass bottles, called *carboys*, which are packed in straw. But you will have no use for it; the ordinary sulphuric acid is quite strong enough, and in using it, if you follow the directions previously given, you will have no trouble with it. The acid you use will most likely be brown in color; this is due to some impurity derived from dust in the air.

Ether, or sulphuric ether, as it is called, is a colorless liquid which looks like alcohol. It has a very pleasant odor, although, if you have made its acquaintance only in the sick-room, where it is used as an *anæsthetic*,* it may not seem fragrant to you. Buy a small bottle of this at a drug-store, and, when you are not using it, *keep the bottle in a cool place* and *wel-corked*, because the vapor of ether is inflammable. Pour a little into your hand, and you will discover that it evaporates quickly; in other words, it is *volatile*, and substances having this quality boil at low temperatures.

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* Anæsthetic, a substance used to cause insensibility to pain.

It is sometimes used in cleaning woolen and silk garments. It dissolves fats, oils, and resinous substances more quickly than alcohol does.

EXPERIMENT 1.—Test sulphuric acid by litmus. Does it seem like the other acids?

EXPERIMENT 2.—Dip a pine shaving into sulphuric acid; also "try" it upon straw, woolen and cotton goods, and upon paper, linen, and chamois-skin. Note the effect in each case.

EXPERIMENT 3.—Fill a bottle half full of sulphuric acid, and mark on the glass, with ink or pencil, just the point touched by the liquid. Leave the bottle, *uncorked*, where it will not be disturbed; at the end of twenty-four hours observe if the acid *still just* touches the mark. Make a similar observation every day for two weeks. What do you discover?

EXPERIMENT 4.—Dip a *quill* pen into dilute sulphuric acid, and write a communication on a postal card with it. Is the writing legible?

Afterward hold the card to the fire to dry. What change is produced by the heat?

EXPERIMENT 5.—Try washing tarnished iron or copper vessels with water to which a little sulphuric acid has been added. What effect?

EXPERIMENT 6.—Pour a little *cold* water into a common cup; *add to this** *gradually* about a third as much acid, and, as you add it, stir the mixture with a small test-tube into which you have previously poured a little ether. What phenomenon do you notice, and how do you account for it?

---

* It is always safest to pour sulphuric acid *into* water, not water into sulphuric acid. Why?

Experiment 7.—Heat a bit of copper with a little sulphuric acid in a test-tube. Test the escaping fumes by holding a moistened red flower over them. What compound has been set free?

Experiment 8.—Repeat Experiment 4, "Carbon," and give explanation.

Sulphuric acid has a powerful affinity for water. It will take the invisible vapor from the atmosphere; it finds it in the driest air, seizes it, and retains it. Indeed, it is so thirsty for it that it sometimes decomposes a compound containing the elements of water (oxygen and hydrogen), catches these, and leaves the other elements free. This explains Experiments 4 and 5, "Carbon."

When sulphuric acid and water are mixed, heat is always given off. Experiment 6 illustrates this.

All the metals, except gold and platinum, are attacked by this acid. Copper is readily dissolved by it, sulphur dioxide escapes, and the excess of oxygen unites with the copper.

EXERCISE XXXI.

Metals.

Collect small pieces of iron, zinc, lead, and copper, and to these add some coins of gold, silver, etc., if you happen to have them. When you have made this collection, find out by the following very simple experiments if the different specimens in it have any points of likeness.

EXPERIMENT 1.—Hold each of the articles mentioned above, between your eye and a strong light. Can you see through any of them?

Put the coins into a glass jar and fill it with water. Can you see the coins through the water? Now slip a piece of window-glass over the mouth of the jar, and observe whether you can still see the coins when looking down through both the glass and water. What difference, then, do you discover between the iron, copper, and coins, and the glass and water?

EXPERIMENT 2.—Take tarnished or dull-looking coins, and, after washing them in vinegar, brighten them by rubbing them with sand, soap, sapolio, or chalk. Can you improve glass by the same treatment?

EXPERIMENT 3.—Heat pieces of iron, zinc, copper, etc., in the flame of a spirit-lamp. Do they heat and cool quickly, or the contrary?

When substances do not let light pass through them, they are said to be *opaque*, while such as readily admit it are *transparent*. The bright, glistening appearance seen on gold and silver, when freshly cut or polished, is due to their power to reflect light, and it is known as a *metallic luster*.

Of the seventy elements, by far the largest number are called *metals;* the remaining ones are *metalloids* (not metals). But this distinction is chiefly one of convenience, for the two classes pass gradually into each other. No clearly defined limit separates them. For example, arsenic and some other elements are sometimes called metals, and sometimes metalloids.

Most of the elements which you have studied—oxygen, hydrogen, nitrogen, carbon, sulphur, iodine, and chlorine—are non-metallic; but iron, lead, zinc, copper, gold, silver, platinum, potassium, and mercury, as also many more, are classed as metals. These last are unlike the others in their general appearance, and in some of their chemical and physical properties. Metals have usually a bright, glistening surface; they are solid,* and can be hammered into thin leaves, or drawn into wire.

All metals are opaque, except occasionally when they are in extremely thin layers.

The most important difference between the two classes is a chemical one, which you are not quite far enough advanced to understand.

The property of the metals by which we can beat them into sheets is called *malleability*. Gold is more malleable than other metals. A single grain of it may be flattened until it will cover almost fifty square inches.

Ductility is the quality by which the metals are drawn into wire. Iron is very ductile. These two properties, malleability and ductility, render these elements extremely useful.

The metals are not generally found alone, but combined with oxygen, chlorine, sulphur, or some other metalloid. These native compounds or combinations are *metallic ores*. They are found in the earth in mines, and in the rocks that form hills and mountains. A very few metals are found *native*—that is, unassociated with other elements. Gold and platinum are examples of the latter class.

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* Mercury is the only metal which is liquid at ordinary temperatures.

The following table shows the order of malleability and ductility of the most common metals:

MALLEABILITY.	DUCTILITY.
Gold.	Platinum.
Silver.	Silver.
Copper.	Iron.
Tin.	Copper.
Lead.	Gold.
Zinc.	Zinc.
Platinum.	Tin.
Iron.	Lead.

EXERCISE XXXII.

Iron.

PROVIDE some pieces of wrought-iron and cast-iron. You can probably get them at a blacksmith's shop. Study the peculiarities of these pieces, by observing their color, examining their *broken* surfaces under the magnifying glass, listening to the sound made when they are dropped or struck by a hammer, and finally, bring the magnet used in Exercise I near them.

Also, have at hand a common kitchen knife, knitting-needles, some nails, iron filings, and, in addition, get if you can some of the mineral "pyrites." It is yellow and bright, and looks like gold. Perhaps you can find out if it is valuable.

Experiment 1.—Bend a knife-blade and knitting-needle, also iron nails, if you can.

Experiment 2.—Hold a knitting-needle in a spirit-lamp flame until it becomes red hot; then quickly drop it into cold water, and afterward break it. Has this heating and cooling had any effect?

Experiment 3.—Heat and cool another knitting-needle; afterward *re*heat the needle and cool it *slowly;* then bend to break as before; also observe changes of color * during the second heating.

Iron is the most abundant and useful of the metals. It was known a long time ago, as you will discover from reading early history. It is found uncombined only in very small quantities, and the processes by which it is obtained from its ores were not known to the early races. Pure iron has a bright white color and is tough though soft, but the iron which we usually see has a large proportion of carbon in it. There are three kinds in common use—*wrought-iron, steel,* and *cast-iron.*

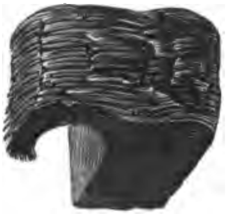

Fig. 63.

Wrought-iron is the purest variety; its structure is *fibrous:* that is, composed of threads or fibers (see Fig. 63) of the metal. It can be hammered or worked, when it is red hot, into any shape. When two pieces of red-hot iron are hammered into one, they are said to be *welded* together. It is used for articles requiring strength, without elasticity or hardness.

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* It is customary to heat tools for cutting metal to a pale-yellow color, knives to a dark-yellow, chisels and hatchets to a slight purple-yellow, and springs till they are decidedly purple or blue. They are afterward slowly cooled. These different tints are due to a film of iron oxide which is formed on the metal when it is heated.

Steel is iron containing more carbon than wrought-iron. It is harder and tougher. By repeated heating and cooling almost any degree of elasticity may be given to it, and this quality adapts it to things requiring elasticity, hardness, and strength.

Cast-iron contains still more carbon. It is brittle, and its broken surface presents a granular appearance (Fig. 64). It is called cast-iron because, when melted and poured into a mold, it readily takes the shape of the form, and thus a "casting" is obtained. This kind can not be welded, hammered into sheets, or drawn into wire.*

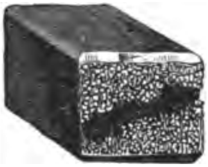

FIG. 64.

EXPERIMENT 4.—Drop a little nitric acid on a piece of polished steel, and also on a piece of iron. What effect?

EXPERIMENT 5.—Leave a piece of polished iron out in the dew for a night. What happens?

EXPERIMENT 6.—Moisten half a teaspoonful of iron filings with water, and drop them into a clean bottle so that they will adhere to its bottom. Invert this bottle in a bowl of water, and leave it for a few days in a warm place. What change takes place in the height of the water, and how can you account for it?

---

* It will be found a useful exercise for the pupil to decide from the general statement given above, which kind of iron is best adapted for certain specific uses; for example, what should be used for pots, kettles, stoves, stove-pipes, horseshoes, knife-blades, razor-blades, railroad-bridges, watch-springs, etc., and why.

Experiment 7.—Hold a piece of iron in the flame of a spirit-lamp. Will it burn? File the piece of iron, and allow some of the filings to fall into the flame. Will they burn?

When iron is burned in the air, oxide of iron is the product (Exercises XVI and XVIII). The same compound is formed when untarnished iron is exposed to dampness and *rusts*. If iron and oxygen united form an iron oxide, what do you think iron and sulphur will form? Bear in mind that a name ending in *ide* shows us that two things are combined. Iron sulphide is the iron pyrites, crystals of which look like gold. This resemblance has led many ignorant people to suppose that they have discovered the precious metal, and they are disappointed to learn that it is only "fool's gold."

Experiment 8.—Heat a shovel red hot, and sprinkle a very little iron pyrites on it. Observe the smell of burning sulphur.

Experiment 9.—Place a piece of "fool's gold" on a flat stone and strike it with a hammer. Is it broken or merely flattened? Bear in mind that gold is malleable, but can not be easily broken.

Experiment 10.—Pour a little dilute sulphuric acid on a few iron filings in a glass vessel. When the effervescence or chemical action ceases, add some water and filter the liquid through filter-paper. Evaporate the filtered liquid, taking care to remove the dish from the heat as soon as it begins to "spit." Finally, observe the green crystals left on cooling in the dish.

Sulphuric acid combined with iron forms a salt (Exercise XV), the chemical name of which is *sulphate* *of iron.* The common name for it is *copperas* or green vitriol. This is used in dyeing, in making ink, and as a disinfectant.

EXERCISE XXXIII.

Copper, Lead, Zinc, and Tin.

CONTINUE the study of the metals, and for this purpose you will want some bright pieces of copper, lead, and zinc, and some copper wire; also provide half an ounce of sugar of lead (lead acetate) and a little blue vitriol (copper sulphate) and lunar caustic (silver nitrate). The three compounds mentioned are poisons, which should be used with care. The last ones you probably have on hand.

Examine the pieces of metal just as you did the iron. Make careful observations upon their color, structure, and hardness, and use the magnet to determine their magnetic quality. What peculiarity always distinguishes the copper, and how may you know lead from zinc?

EXPERIMENT 1.—Try the effect of the strong acids upon copper, lead, and zinc. Are these metals corroded by them?

EXPERIMENT 2.—Hold a piece of fine copper wire in the flame of a spirit-lamp for a few moments. Notice the color of the flame.

EXPERIMENT 3.—Expose a piece of untarnished copper to the open air for twenty-four hours. Does it rust? Also leave another piece in pure water. Does this rust?

EXPERIMENT 4.—Try the effect of exposure to air and moisture on the lead, zinc, and tin. How are they affected?

Next to iron, the most useful metals are copper, lead, zinc, and tin. They are elements, though obtained chiefly from compounds, or ores (Exercise XXXI) found in the earth. Their symbols * are for copper, Cu; lead, Pb; zinc, Zn; tin, Sn.

Pure or native copper is found in large quantities in the neighborhood of Lake Superior.

Copper is used for making water-boilers, cooking-utensils, telegraph-wires, and sheets of it cover the parts of ships exposed to the water. When copper unites with other substances, poisonous compounds are formed; on this account, copper cooking-vessels should be kept perfectly clean and bright, and acid fruits should not remain long in them.

Metals are sometimes mixed together when in a melted state. Such mixtures are called *alloys*. *Brass* is an alloy of copper and zinc; *bronze*, an alloy of copper and tin. Watch-cases in imitation of gold are sometimes made of an alloy called *pinchbeck*. This alloy is of copper mixed with a large proportion of zinc. Cases made of this look like gold ones, but they tarnish more easily, and by this the deception may be discovered.

EXPERIMENT 5.—Make a saturated solution of blue vitriol † by dissolving it in hot water; put an iron knife-blade into this solution; leave it for five or ten minutes; then take it out, and observe the appearance of the blade (Fig. 65.) Rub off the surface. What has happened to the iron?

---

* The Latin names for copper, lead, and tin are *cuprum*, *plumbum*, *stannum*. The first letters of these are the symbols used, instead of the corresponding letters of the English names.

† Sulphuric acid combines with several of the metals, forming compounds called *vitriols*. Thus, iron sulphate is *green vitriol* (Exercise XXXII), copper sulphate is *blue vitriol*, and zinc sulphate is *white vitriol*.

EXPERIMENT 6.—Bend a piece of copper wire into any compact form, and put it into a small glass; cover this with lunar-caustic solution (silver-nitrate solution). Soon examine the copper and note any change.

Experiments 5 and 6 are fine illustrations of chemical affinity, and of the reactions which take place when this force is active. You should study them until you are able to explain the changes involved. To understand these, bear in mind that in each case you first dissolved a salt consisting of an acid and a metal. Blue vitriol is a compound of sulphuric acid and metallic copper, and lunar caustic consists of nitric acid and silver. Also bear in mind that the strong acids seem, sometimes, to show preferences, and frequently they give up one thing that they may unite with another which they have a stronger affinity for. This explains the copper on the knife-blade and the silver on the wire. In the first case, the sulphuric acid forsook the copper and joined the iron; the two metals changed places—the copper appeared on the knife, and iron sulphate was dissolved in the water. Similar changes occur in Experiment 6.

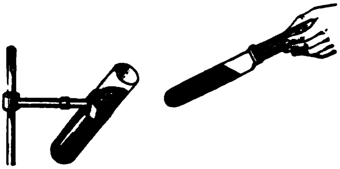

FIG. 65.

Copper in combination is easily detected. Ammonia is a test for the copper compounds (see Experiment 6, Exercise XXI) and the decomposition of a compound (Experiment 5) is also a test, for there is no danger of mistaking pure copper, whose color is unlike that of any other metal.

Lead is found only in a state of combination. It is largely used for water-pipes; but the salts of lead, like those of copper, are poisonous, and sometimes water from passing through lead pipes becomes unfit to drink. Perfectly pure water does not corrode lead (Exercise XIX), but if air is present, lead oxide is formed, and this dissolves in water, and thus renders the water unwholesome. Lead is also used for making shot and bullets. It is alloyed with other metals. The men who work in lead are called *plumbers*. Some of the lead compounds are very useful. Several of them are used as paints.

White lead is lead carbonate.

Litharge is lead oxide.

Red lead is lead dioxide.

Sugar of lead is lead acetate.

EXPERIMENT 7.—Dissolve half an ounce of sugar of lead (lead and acetic acid) in a teacupful of rain-water. If the solution is not clear, add a tablespoonful of good vinegar to the solution. Pour the solution into a wide-mouthed bottle or tumbler, and suspend in it a stick or bar of metallic zinc, either by fastening it to the cork, or as seen in Fig. 66. Set the vessel carefully aside for twenty-four hours. Explain the changes which occur.

Zinc, on account of its greater hardness, is better than lead for some purposes. It is not tarnished by exposure to either moist or dry air, and hence it is largely used in the form of sheets. It lines refrigerators, and is put under stoves and before fires. *Galvanized iron*, as it is called, is iron coated with zinc, by dipping it into melted zinc.

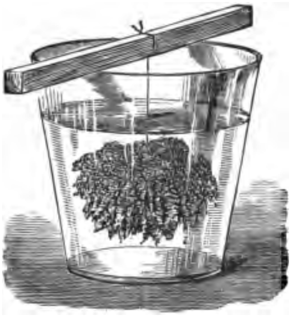

FIG. 66.

German silver is an alloy of copper, zinc, and nickel. The latter is a rare metal which resembles silver.

EXPERIMENT 8.—Dissolve some small pieces of zinc in hydrochloric acid or sulphuric acid, and hydrogen is given off (Experiment 1, Exercise XVIII). If you filter the liquid left in the bottle, and afterward let the moisture evaporate, what compound will you finally obtain if you have used hydrochloric acid? What if you used sulphuric acid?

Tin is not a very common metal. It is only obtained from its ores. The most famous tin-mines are in Cornwall, England. A very little has been found in Maine, New Hampshire, and California. The tinware seen in common use (pans, basins, pails, etc.) is not all tin, but sheet-iron coated with tin. This does not rust or tarnish until the tin is worn off, and the iron thus exposed to air and moisture.

APPARATUS REQUIRED FOR EXPERIMENTS.

Beakers.
Bottles.
Clay pipes.
Coins.
Corks.
Crucible.
Files.
Fine sieve.
Florence flasks.
Glass cans.
Glass tubes.
Horseshoe magnet.
Iron nails.
Iron knife.
Kitchen cups.
Knitting-needles.
Measuring-glass.
Mortar and pestle.
Pneumatic trough
Pocket magnifying-glass.
Retort.
Retort stand.
Scales.
Spoon.
Spirit-lamp.
Sponge.
Tallow candles.
Test-tubes.
Thermometer.
Tumblers.
Tunnel.
Wash-bottle.
Window-glass.
Wire gauze.

MATERIALS REQUIRED FOR EXPERIMENTS.

Acid, hydrochloric.
Acid, nitric.
Acid, sulphuric.
Alcohol.
Alum.
Aqua ammoniæ.
Bicarbonate of soda.
Black oxide of manganese.
Blotting-paper.
Blue vitriol.
Bluing, laundry.
Bone-black.
Borax.
Camphor gum.
Camphor solution.
Castor-oil.
Caustic potash.
Chalk.
Charcoal.
Sal ammoniac.
Salt.
Saltpeter.
Sand.
Sawdust.
Shot.
Chlorate of potash.
Chloride of lime.
Cochineal.
Coffee.
Copperas.
Copper wire.
Copper filings.
Cream of tartar.
Ether.
Fats.
Filter-paper.
Flowers.
Flowers of sulphur.
Flour.
Glauber's salt.
Glue.
Glycerin.
Gold-leaf.
Gum-arabic.
Iodine.
Soap.
Spirits of turpentine.
Starch.
Sugar.
Sugar of lead.
Sweet-oil.
Iron filings.
Iron pyrites.
Iron wire.
Lead strips.
Lime-water.
Litmus paper.
Litmus tincture.
Lunar caustic.
Milk.
Molasses.
Pieces of metals, iron, zinc, and copper.
Pieces of limestone or marble.
Plaster of Paris.
Purple cabbage.
Rhubarb root.
Red oxide of mercury.
Rosin.
Roll-sulphur.
Turmeric root.
Unslaked lime.
Vinegar.
Washing-soda.
Wax.

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